ANÆSTHETICS
IN PRACTICE AND THEORY

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A TEXT-BOOK FOR
PRACTITIONERS
AND STUDENTS

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CHAPTER I

INTRODUCTORY AND HISTORICAL

THE art of giving anæsthetics is ancillary to that of surgery. The brilliant development of the latter in modern times has inevitably stimulated the progress of the former, on which at the same time it has partly depended. It has even happened that, in intra-thoracic surgery, an extension of the lesser has opened the way for fresh advance by the greater sister art. This book endeavours to put before the student and practitioner a comprehensive account of the best current opinion and practice of anæsthetics, as well as the results of the writer's own experience. He hopes to succeed at least in helping those who are beginning to practise this branch of medicine and to interest those who have already gained experience. The attraction even of a practical occupation like anæsthetics is heightened both by a knowledge of its past and by speculation as to its future. Although neither of these may bear directly upon the actual giving of anæsthetics, I have ventured to indulge a little in both.

As might be expected, the history of attempts to produce unconsciousness as an aid to surgery begins hundreds of years ago. Over all this early history I do not propose to linger. It is already to be found in several books,[1] and will be but the same if repeated in another. Suffice it to say that although the most ancient writings, the Bible, the Talmud, the "Odyssey" of Homer, contain references to the use of drugs for alleviation of pain, the first known reference to such use in order to combat the pain of a surgical operation is found in the works of Dioscorides, who was a contemporary of Pliny, who died in 79 A.D. Pliny himself speaks of the juice of certain leaves taken before cuttings and burnings to produce sleep.[2]

The root and the leaves of the mandrake (*Atropa mandragora*) were the narcotic agent employed in those far-off days, and it is instructive to notice that an allied plant, belladonna, has come recently into extensive use in connection with the induction of anæsthesia. Indian hemp (*Cannabis Indica*) was used by Hoa-Tho, a Chinese practitioner of the third century. From the

[1] "Anæsthetics and their Administration": Hewitt, 4th edition, p. 2.
[2] "Art of Anæsthesia": P. J. Flagg, p. 1 (Philadelphia).

account of its effects Snow [1] believed that Hoa-Tho gave his patients the drug by means of inhalation of its fumes, and he operated while they were under its influence. About ten centuries later Theodoric, who lived in Italy, describes "the making of a flavour for performing surgical operations, according to Dominus Hugo." The "flavour" was made from opium, mulberry, hyoscyamus, hemlock, mandragora and other plants, and applied on a sponge to the nostrils of the patient. Snow shows that we have as good reason to doubt the efficacy of this "*spongia somnifera*" as we have to deny any analgesic properties to the compound of antimony, quicksilver, lime and arsenic, which Hugo applied locally to an operation site. "It is reasonable also to conclude," writes Snow, "that if any successful plan of preventing the pain of surgical operations had been introduced after the revival of literature, it would not have fallen into disuse and been forgotten." It is certain, however, from the oft-quoted extract from the writings of Du Bartas,[2] that in the Middle Ages it was common for surgeons to produce some kind of insensibility in the patient on whom they were about to operate. In the seventeenth century compression of the vessels of the neck was employed to produce unconsciousness, and this practice is attributed to the Assyrians in ancient times. Compression of large nerves to produce local insensibility of a limb, a more scientific procedure, was tried in the eighteenth century, and John Hunter amputated a leg with the aid of this form of anæsthesia. About this time "animal magnetism" or "mesmerism" (Anthony Mesmer, 1766) was practised for the production of insensibility, and nearly a century later Esdaile in India had wide success in performing painless operations upon natives who had been hypnotised. The use of hypnotism was mainly due to the writing of James Braid.[3]

Hypnotism is a powerful but uncertain method of producing anæsthesia. It has been widely studied by modern neurologists, and a fuller understanding of the condition leads to the opinion that as an aid to surgery it is inferior to the other methods of anæsthesia at our command. Its effects are more uncertain and less under control. In very exceptional cases, however, it may still happen that hypnotism should be invoked as the best means of quieting a neurotic patient. Indeed, it has been truly said that a large element of "suggestion" plays a part in the tranquil-

[1] "On Anæsthetics": John Snow, 1858, pp. 4 *et seq.*

[2] "Even as a surgeon . . .
Bringeth his patient in a senseless slumber,
And griefless then, guided by use and art,
To save the whole cuts off the infected part.

[3] "Braid on Hypnotism," edit. 1899.

lising effect which the skilled anæsthetist produces in the nervous patient by his manner, actions, and speech, apart from his drugs and his manipulations. Under the term "hyponarcosis" Professor Friedlander describes a process in which the two agents of anæsthesia, hypnotism and inhalation of narcotics, are combined. Narcosis is gradually grafted upon a hypnotic state.[1] After operation hypnosis is employed again, and it is asserted that the amount of anæsthetic required is diminished and after-effects proportionately reduced by the process. With hyponarcosis we have jumped to the present. We must turn back to the nineteenth century.

The discovery of inhalation anæsthesia did not arise, as Snow points out, from previous efforts at alleviating the pain of operations. It arose directly from the practice of inhaling medicinal substances. The custom of inhaling the fumes of narcotic plants is alluded to so far back as the days of Herodotus. It was not till near the end of the eighteenth century, however, that this practice was scientifically used and investigated. At this time the discovery of hydrogen by Cavendish and of oxygen and nitrous oxide by Priestley shed a new light upon and gave a fresh impetus to the study of the inhalation of gases. In 1800 Humphry Davy wrote that "as nitrous oxide . . . appears capable of destroying physical pain, it may probably be used with advantage during surgical operations. . . ." In this year, too, was born the man to whom is due the credit of being the first to experiment with the direct aim of producing by inhalation a condition of insensibility during operation. The name of Henry Hill Hickman has been but recently rescued from oblivion.[2] A place in the front rank is assured to it for all time in the minds of those who study the origin of surgical anæsthesia. Whether for the humane reasons which prompted him, the originality and courage that guided and sustained him, the neglect that was meted out to him or the early death that put an end to his endeavours, Hickman's name should always be revered as that of a great, though an unfortunate, English pioneer. Hickman experimented on puppies and mice with air exhaustion and with carbon dioxide, slowly prepared, and run in through a tube to the animal under glass. He convinced himself that "suspended animation may be continued a sufficient time for any surgical operation providing the surgeon acts with skill and promptitude." In reading these words we must remind ourselves of the surgery of the period, and that practically all serious operations were of but short duration. Meeting only with discouragement in his own country, Hickman

[1] *Lancet*, April 16, 1921, p. 814.
[2] *Brit. Med. Journal*, April 13, 1912, p. 843.

addressed himself to France, and succeeded so far that the Academy of Medicine in Paris nominated a committee to consider his letter. Of that committee the great surgeon Larrey alone saw any value in the young surgeon's views and experiments. No practical steps were taken, and Hickman returned home to die at the age of twenty-nine. Later (1847), when controversy raged as to whose should be the credit for inventing inhalation anæsthesia, it was a French Academician, M. Gerardin, who recalled the communication of Hickman and stated that he had asserted that "by the inhalation of laughing gas he could render patients insensible to pain during surgical operations." "The discovery of the method of performing operations with the aid of medicated vapours is Hickman's property" (*Medical Times*, 1847), but the credit of getting that discovery known to the public and acted upon by the medical profession is due to others in another country.[1] It is in America that we find the first successful practical exploitation of anæsthesia. In 1842 Crawford Long, a country practitioner, used ether upon his own patients. He did not take steps to make his discovery widely known until a claim arose for public recognition and reward. This was after Horace Wells (1844), a dentist of Hartford, Connecticut, had produced anæsthesia by nitrous oxide, and Morton, a dentist of Boston, and Jackson, a Professor of Chemistry, had put themselves forward as the originators of anæsthesia owing to their administrations of ether (1846). Horace Wells, although successful with it in his own practice, failed to bring nitrous oxide into general use, largely owing to the failure of a demonstration at the Massachusetts General Hospital. It was widely known that the actions of nitrous oxide and of ether were similar, for lecturers were in the habit of illustrating their effects in public. It was from the observed behaviour of persons under the influence of ether that Long had been induced to try it in surgery. The credit due respectively to the American pioneers is well summed up in a letter of the late Sir William Osler[2]: "While the accepted rule that scientific discovery dates from publication is a wise one, we need not withhold from Dr. Long the credit of independent and prior experiment and discovery, but we cannot assign to him any influence upon the historical development of our knowledge of surgical anæsthesia, or any share in the introduction to the world at large of the blessings of this matchless discovery." "Surgical anæsthesia as a practical procedure dates from October 16, 1846, when William Morton, in the Massachusetts

[1] "Anæsthesia": J. T. Gwathmey (Appleton, New York and London), 1914. Gives full details of the origin of anæsthesia in America.

[2] *Lancet*, November 21, 1914.

General Hospital, Boston, gave ether to Gilbert Abbott, upon whom Dr. John Collins Warren performed a painless operation." The first operation under the influence of ether that can be traced in this country took place on December 9, 1846. It was the extraction of a tooth, both the operation being performed and the ether administered by Dr. Robinson, of Gower Street. Two days later Liston amputated a thigh under ether at University College Hospital. In a short time news of the great discovery, which came to England from Dr. Bigelow, spread, and ether was in use for the prevention of pain during surgical operations all over the civilised world. The irritating nature of ether vapour and the crude methods by which it was given led to its supersession by chloroform, when Sir James (then Dr.) Simpson introduced this drug in a paper read before the Medico-Chirurgical Society of Edinburgh (1847). Chloroform was recommended to Simpson by Waldie, a chemist of Liverpool. The new drug, convenient to administer and far less unpleasant than ether to inhale, soon took the first place as an anæsthetic. It was not long, however, before its inherent dangers asserted themselves, and, although ether was used for eleven months in Europe and sixteen in America before a death occurred, the first fatality with chloroform happened when it had been in use only two or three months. Others followed, and led to renewed caution with regard to chloroform and efforts to render more convenient and agreeable the safer but less attractive ether.

Most great advances in any branch of knowledge meet with opposition. Anæsthesia, too, was not without its opponents, and moral grounds were relied on for combating the beneficent aid of chloroform and ether, particularly in childbirth. It is said that the courage of Queen Victoria in deciding that chloroform should be used at her own labours did much to shatter prejudices against its employment.

More still was effected by the work of John Snow, who laboured to place inhalation anæsthesia on a basis of scientific knowledge. Snow was a successful practical anæsthetist as well as an experimenter, and his work "On Chloroform and other Anæsthetics" (1858) may be regarded as the foundation on which has been erected the modern art of anæsthesia. John Snow, the eldest son of a farmer, was born at York in 1813. At the age of fourteen he was apprenticed to a surgeon in Newcastle-on-Tyne. During his stay there an epidemic of cholera afforded him the opportunity of making observations which he put to good account later. In 1836 Snow studied in London at the then existing Hunterian School of Medicine, in Windmill Street, and at the Westminster Hospital. A fellow-student of that time writes that, "not

particularly quick of apprehension, or ready in invention, he yet always kept in the foreground by his indomitable perseverance and determination in following up whatever line of investigation was open to him. The object of this steady pursuit with him was always truth; the naked truth for its own sake was what he sought and loved." Snow set up in practice in Frith Street, Soho, where his biographer, Sir B. W. Richardson, thus describes him: "He kept no company, and found every amusement in his science books, his experiments, his business and simple exercise." In 1841 Snow published his first paper on "Asphyxia and the Resuscitation of New-born Children."[1] In 1846 came the report from America of painless operations under the influence of inhaled ether, and Snow at once set to work on the new facts, for the investigation and proper utilising of which his previous experiments had so well prepared him. He soon showed that failures with ether were due to faulty methods of administration. At St. George's Hospital and at University College Hospital he was enabled to demonstrate the value and success of the methods and apparatus that he devised. In 1847 he published a book which embodied his experience. When chloroform was introduced, Snow was quick to recognise its superiority over ether as generally given at the time. He was equally quick to investigate the new anæsthetic in his own thorough way, and was able to define the dangers of chloroform and to explain some of them in a manner which subsequent and more elaborate investigations have never excelled or contradicted. He realized and pointed out the necessity for the administrator of anæsthetics being skilled if safety were to be secured, and derided the practice of the time by which "at some of our hospitals the administration of chloroform has been entrusted to the porter, who would only grin in ignorance if informed that each time his services were required he performed the grand act of suspending for the time the oxidation of the whole body, and of inducing a temporary death." Searching always for a perfectly safe anæsthetic, Snow experimented with many substances, and at one time thought that in amylene he had found his ideal. Deaths, however, occurred, as he has recorded, in his own hands, and he discontinued its use. Snow's labours with anæsthetics did not exclude him from interest in other branches of medicine, and it is worthy of note that he was able in 1854 to demonstrate the cause of an epidemic of cholera which raged around the pump of Golden Square, Soho. Snow died in 1858, but not before he had finished his great work "On Chloroform and other Anæsthetics," which was edited and published in the same year by his friend Richardson. The

[1] *London Medical Gazette*, November, 1841.

imperishable value of Snow's labours is due to his having submitted the broad facts of inhalation anæsthesia to the test of scientific experiment in order to find out upon what they depended, and thus to discover trustworthy principles on which to give anæsthetics with safety and with certainty. Fortunately his ability as an experimenter and an anæsthetist was equalled by his powers of telling clearly and forcibly the story of his work and the canons of practice which he deduced from it. Those who followed Snow had lines laid down upon which to work. He had shown that a chief danger of chloroform was too great concentration of its vapour and that fatalities could be largely avoided by the exercise of care and skill. He had shown that ether could be robbed of its chief defects by proper apparatus. Joseph Clover developed these principles and employed his great mechanical ingenuity in devising apparatus to secure safe percentage vapours of chloroform and gradual regulated supply of ether vapour. His experiences with chloroform have been confirmed by many subsequent administrators, and showed that danger is not entirely eliminated by keeping the vapour weak. Impressed by the greater safety of ether, Clover devoted pains to perfecting apparatus for giving it with convenience both to patient and anæsthetist, and his small regulating inhaler was for years a boon, and is in modified form still a suitable instrument in many cases. Clover also introduced the practice of preceding ether by nitrous oxide, for which purpose he devised appropriate means. The latter anæsthetic had suffered eclipse by the failure of Wells' demonstration. Colton, an American chemist, succeeded, however, eventually in bringing this agent to the place it deserves. It was at Colton's lectures that Wells had perceived the possibility of painless tooth extraction, but it was twenty years later that Colton demonstrated to Evans, an English dentist in Paris, the successful extraction of teeth from an unconscious patient. As a result of Evans' demonstrations to the Dental Hospital of London a joint committee of the Odontological Society and the Dental Hospital issued a report which was so favourable to nitrous oxide that from that time the gas has held the leading place as an anæsthetic in dental practice. Ethyl chloride, which in practice is in some respects analogous with nitrous oxide, was discovered by Flourens in 1847, and was used for surgery by Heyfelder. It was not until 1895, however, that this anæsthetic was placed in the hands of the profession with the backing of experience and investigation. In this country much credit for that was due to McCardie, of Birmingham. The possibilities of nitrous oxide as an anæsthetic were extended by its combination with oxygen. This was made practicable by apparatus designed by the late Sir Frederic Hewitt,

after carrying out a large number of clinical experiments. Paul Bert had already investigated the phenomena which arose from inhalation of nitrous oxide and oxygen, but had concluded that anæsthesia could not be obtained unless the gases were given under increased atmospheric pressure. Hewitt showed that this was not so, and determined by experiment the proper percentage of oxygen that should be given with nitrous oxide for anæsthesia. His unceasing study of anæsthetics in practice led Hewitt to devise many improvements in technique and apparatus, and also to instigate much valuable physiological research. Perhaps his chief contribution to the principles of anæsthetic administration was his insistence on the importance of maintaining always free and unobstructed breathing. He showed that, whether or not the physiologists were right in insisting that undue concentration of chloroform vapour furnished its chief danger, at any rate in actual practice upon human beings hampered breathing was an equally potent step to disaster. The constant exertions of Hewitt did much for anæsthetics. His book "Anæsthetics and their Administration" summarized and arranged all available knowledge, and in the conduct of his life he left no stone unturned in order to raise the standard of those who were devoting themselves to the practice of anæsthesia and to encourage in all possible ways the welfare of this particular branch of practice. It is hardly too much to say that as a result of his teaching and example a new school of anæsthetists developed in London and spread to the big provincial towns of England. It was largely owing to Hewitt's exertions and constant protests that examining bodies in Great Britain were brought to insist upon candidates for qualifying examinations producing proof that they had received instruction in anæsthetics. He sought to involve the law in preventing the administration of anæsthetics by any but qualified persons, and succeeded in getting a Departmental Committee appointed by the Home Office to investigate the matter. The unsatisfactory state of affairs as regards coroners' inquiries into deaths during anæsthesia was well shown during this investigation, and it is a misfortune that the European War and later Hewitt's death left us with no more definite outcome from the Committee than some valuable recommendations which there appears to be no chance of carrying out in the near future.

Hewitt was as successful in practice as he was in teaching and propaganda, and his name will long be remembered as the first anæsthetist to be honoured with a Royal appointment, and later with the dignity of a title. It will be remembered in this connection that it was Hewitt who was chosen to administer the anæsthetic to King Edward VII. when he underwent that

operation for acute appendicitis which caused the postponement of his coronation in 1902.

The physiology of anæsthesia, which may be said to have started with Snow's investigations into the proper percentage vapours of chloroform to use and the manner in which undue concentrations produced fatal effects, received increasing study as anæsthetics became more and more established in practice. In 1864 a committee of the Royal Medical and Chirurgical Society, appointed "to inquire into the Uses and the Physiological, Therapeutical and Toxical Effects of Chloroform," issued a report which confirmed much of Snow's doctrine and recommended as a substitute for chloroform the mixture of alcohol, chloroform and ether which has since been widely used and known as the A.C.E. mixture. A more purely physiological research was carried out by a committee of the British Medical Association, whose report was issued in 1879. They found, as Snow had done, that in chloroform deaths breathing generally ceased before the action of the heart, but that the opposite might occur. At this time it was strenuously maintained by the Scotch school of surgeons, following Syme, that chloroform never killed except by paralysing the respiration. Syme taught that the pulse might be, and should be, neglected and attention focussed entirely upon the patient's respiration. This difference of opinion has been responsible for much physiological study of chloroform as well as for much violent controversial writing. The two Hyderabad Chloroform Commissions financed by the Nizam of Hyderabad at the instigation of Surgeon-Major Laurie, a staunch disciple of Syme, carried out large numbers of experiments and arrived at the conclusion that Syme's views were correct (1891). The work of the second Commission and its conclusions were, however, alike subjected to destructive criticism by leading physiologists. Important independent observations were made by many of the latter, and the general conclusion with regard to fatal effects from chloroform may be said to be that this drug has a direct depressing action upon the heart when administered to the degree of full anæsthesia, and that although the respiration often fails first, yet when death occurs it is the effect upon the heart and circulation, not that upon the respiratory centre, which is the fatal cause. This view is in agreement with what is seen in clinical practice. There we are familiar with two kinds of dangerous states in chloroform anæsthesia. In the first the respiration gradually fails along with an increasing pallor and enfeebled circulation. Such patients can usually be saved by prompt attention to the breathing. In the other condition there is sudden total collapse. The patient is at once

pulseless, though the breathing may flicker on for a few irregular gasps at intervals. These are the characteristic cases of chloroform syncope occurring early in the administration. They have been attributed by Goodman Levy, as we shall see later, to ventricular fibrillation, and for them we have at present no remedy but to avoid induction of anæsthesia by chloroform. For our physiological knowledge of chloroform we are indebted among English workers chiefly to Gaskell, Shore, Leonard Hill, Sherrington, and Waller. The way in which chloroform is taken up and carried by the blood and its interaction with the blood-gases have been studied and described by Buckmaster and Gardner. Toxic effects of chloroform, which may appear only at considerable intervals after the inhalation, have been studied since the late Dr. L. Guthrie's paper in 1894 drew attention to the condition sometimes known as "delayed chloroform poisoning." Knowledge of this post-anæsthetic state, its relationship to acidosis, and the pathological conditions accompanying it have been the object of much physiological and clinical experiment, without, however, bringing us yet to definite understanding of essential causes. The teachings of physiology brought practical efforts to avoid the dangers that had been shown to accompany inhalation of chloroform. The physiologists having shown that safety lay probably in regular inhalation of a uniformly weak vapour, instruments were designed to make this possible. Hence sprang the Dubois inhaler, the Roth-Dräger apparatus, Waller's chloroform balance, and Vernon Harcourt's inhaler. These forms of apparatus abolished, it is true, the possibility of giving a vapour stronger than that which physiology had declared safe, and they were of high educational value, making it easy for the student to see what vapour he was actually administering, and thus to learn its effects. They had, however, the defects of their good qualities, and induction became inconveniently protracted, while a sufficient depth of narcosis could not be maintained with difficult subjects. The success of the laboratory, in fact, is not always to be translated into equally favourable clinical results. Moreover, these machines were mostly cumbrous. With the exception of the Vernon Harcourt inhaler, therefore, the most portable of them, the chloroform regulating apparatus has largely fallen into disuse in this country. Further reasons for this lie in the improved methods of ether administration, the use of preliminary injections which widens the field for ether, and the improved apparatus for giving nitrous oxide and oxygen which has brought this anæsthetic to a high place in the anæsthesia of major surgery. Thus the Gordian knot of chloroform danger has been untied by cutting it. If anæsthetists have not succeeded in robbing chloroform

of its perils, at any rate they have learned to get good results without using it. Much of this progress has been due to American work. From that country came the ideal of shockless operation, and the practice of combined local and general anæsthesia as founded by Crile upon his physiological experiments. American physiologists and anæsthetists have expended trouble and imagination in contriving numerous forms of apparatus for smooth and prolonged administration of nitrous oxide and in exploring the principles of the anæsthesia obtained. Their efforts have met with much success. The names of Gatch, Connell, Teter and Gwathmey are prominent in this work, and their designs have been imitated and sometimes improved in Great Britain. The experiences, too, of the Great War have led to further advances in the use of anæsthetics. There anæsthetists were faced with the necessity of seeking to steer into safety thousands of men who had to be operated upon during the extreme effects of hæmorrhage, shock and exposure. From their results we have learned the value of "gas and oxygen" in such conditions and the danger of spinal anæsthesia in some of the very circumstances where most we would have expected its help. This method, first used by Bier in 1894, has, however, firmly established its value for certain types of operation and of patients in civil practice, especially when used in conjunction with the unconsciousness produced by light forms of general anæsthesia. Apparatus, such as that of Shipway, designed to administer warmed vapours of uniform strength, also proved its value. Much, too, was learned in the treatment of shock which is of inestimable value in civil practice. Thus the value of infusion in this condition has been enormously heightened by Starling's introduction of his gum arabic solution, a direct outcome of war work, and the efficacy of direct blood transfusion was demonstrated on a scale hitherto impossible. The technique of these measures has proportionately improved. The rectal administration of ether has, through the work of Gwathmey, been rendered safe and of great value under certain circumstances. Intratracheal insufflation, a method which we owe in the first instance to the work of Meltzer and Auer, and Elsberg (1909), has assumed a leading position among the methods of anæsthesia for intrathoracic operations and for extensive procedures involving hæmorrhage into the mouth and air passages. Electric anæsthesia described by Leduc has been successfully employed, and it may well be the precursor of a widely-adopted method. Lastly, we must mention the favour with which some surgeons regard a form of anæsthesia which depends upon injections of morphia and scopolamine ("twilight sleep") in conjunction with local

analgesics. The progress of modern anæsthesia cannot be fully related without drawing attention to the increasing importance of local methods. Naturally this is most evident in countries where general anæsthetics have not received the special study which has been bestowed upon them in Great Britain and in America. Consequently it is in France and Germany chiefly that the principles and technique of local analgesia have been evolved and promulgated. The works of Tuffier, Reclus, Schleich and Braun, among others, have given us local methods of wide application. The advantages of combining local and general methods are becoming more and more apparent. The anæsthetist to-day has, it will be seen, many methods at his disposal. No little part of his success depends upon his choosing for each case not only the right anæsthetic agent, but also the right mode of administering it. It is not surprising, therefore, that increasing stress should be laid at the present time upon the importance of his examining the patient at leisure on an occasion prior to the operation.

The right course can then be determined both as regards preliminary medication and the method of anæsthesia to be adopted. All the circumstances of the anæsthesia can be arranged beforehand, and in addition, when the time comes, the patient will not be confronted with an entire stranger, a consideration that weighs heavily with many patients at a moment which is for them a peculiarly trying one.

As the art of giving anæsthetics has thus advanced from those crude efforts when, assisted by a strong porter or efficient straps, the administrator drenched a struggling patient with ether vapour from an unwashed felt cone, to the practice of to-day, with its quiet induction in a prepared patient, its spinal injection or its intratracheal insufflation, so the professional status has improved of those who devote themselves entirely to the practice of anæsthetics.[1] It is true that even to-day the general public is largely unaware of the responsibilities of the anæsthetist or of the extent to which the success of surgery may depend upon his competence. In the medical profession itself these are acknowledged, and care is taken in the education of the medical man and in the staffing of hospitals that the claims of anæsthesia are duly met. The chief examining bodies require evidence that candidates have had instruction in anæsthetics, and the teaching hospitals have expert anæsthetists on the staff either of the hospital or of the medical school. Naturally in a branch which is comparatively young uniformity of position has not yet been attained, and there remains room for improvement, both in the hospital

[1] *Lancet*, Oct. 10, 1908 (leading article).

appointments that anæsthetists hold and in the rewards which the practice offers to them. This will follow only on improvement in the practice of anæsthesia and on a high standard of professional attainment by those who become anæsthetists.

As showing the state of affairs at present in London, it may be mentioned that there are twenty-seven specialists at twelve teaching hospitals. Lectureships recognised by the University of London are held at ten of these hospitals, and at ten of the hospitals the anæsthetists are represented on the committee of the hospital or medical school. Small salaries are paid in most cases, corresponding in some degree to the fees received by the surgeons and physicians for their teaching of the students. It is gratifying that England may fairly be said to have shown the way to the proper recognition of the anæsthetist, and frequent articles in the medical journals of America and of France prove that in these countries too the opinion grows that in this subsidiary branch of practice there should be, as in medicine and in surgery, both position and reward open to those who devote themselves to the practice and the improvement of their specialty. The administration of anæsthetics by specially-trained nurses has found favour in some American hospitals. It is largely disapproved of, however, in other quarters in that country, and cannot be regarded as an arrangement likely to lead to improvement in practice. Only a fully-trained medical man or woman should be entrusted with the care of the narcotized patient, and only such persons are capable of advancing the science and art of anæsthesia.

CHAPTER II

DEFINITION AND NATURE OF ANÆSTHESIA

ANÆSTHESIA, for practical purposes, means a state of complete unconsciousness in which, together with insensibility, there is paralysis of the voluntary muscles and abolition of most of the reflexes of the body. Although the term is often used synonymously with narcosis, the distinction should be made between them that the latter is a wider, looser word, meaning merely the state of insensibility that results from a narcotic drug. Narcosis may amount to anæsthesia if it reaches a certain degree of profundity. Every anæsthesia is a narcosis, but every narcosis is not an anæsthesia. According to this definition, it is not strictly accurate to talk of stages of anæsthesia, since anæsthesia exists only when a particular stage or degree of narcosis is reached. Yet even anæsthesia as thus described can vary within limits above and below. It is not, in fact, a very accurately defined condition, and some latitude in using the word is allowable. Frequently it is used merely to denote insensibility, as when we talk of local anæsthesia. This is generally insensibility to pain, not complete insensibility. It is better to speak, then, of analgesia, and not to use the term anæsthesia in connection with human beings or animals unless unconsciousness is implied in the condition discussed. Recoverable insensibility, or, as we may fairly call it, anæsthesia, is a phenomenon which occurs throughout the living world. The lowliest forms of animal life, and even vegetable organisms, are subject to this change. A **universal effect of anæsthetics,** a first condition, so to speak, of anæsthesia, is **preliminary excitation.** This phenomenon is illustrated both in the vegetable and the animal world. Thus the streaming of protoplasm in plants, *i.e.*, the circulation or rotation of endoplasm within the cell, is affected by anæsthetics in a way exactly comparable to their action on human beings. Dilute solutions of ether accelerate the process; stronger ones retard it, and if their action is protracted, stop it altogether. If the anæsthetic is then withdrawn before its action has been too protracted, streaming may be resumed when the plant is returned to water, just as artificial respiration may restore the patient who has had too much chloroform. Ciliary action is similarly affected; first it

is excited and subsequently inhibited. Alcoholic fermentation is inhibited by chloroform. Photosynthesis (the manufacture of sugar and starch from CO_2 and water in chlorophyll-containing cells) is stopped by placing plants in atmospheres of ether, though the ether is insufficient to stop respiration.[1] The action of chloroform and of ether in suspending the irritability of motile organs of plants (pulvini of *Mimosa pudica*, etc.) is another instance of anæsthesia in the vegetable world. The effects of anæsthetics are put to commercial use by growers of lilac, azaleas, and other plants. It is found that at certain stages of the winter rest of these plants, soon after it sets in and when it is nearly over, if they are subjected to ether vapour and subsequently put under appropriate conditions, flowers are precociously produced. It is known that the so-called repose or rest phase is not one of absolute rest, but that various chemical changes are going on all the time. If the waxing and waning of these changes which take place during the resting phases serve normally as timekeepers to the plant which it interprets as indications to close down or to evoke other activities, such as growth, then it may be supposed that ether interrupts the changes which go on during the rest phase. These changes, which normally served as internal stimuli effecting a slowing-down of respiration and of growth, no longer take place. The plant, released from these constraints, passes directly into its active state, and, finding the conditions in the forcing-house favourable to active growth and its protoplasm whipped into activity by the direct action of the ether, it blossoms forth a week or fortnight sooner than it would otherwise have done. A classic instance showing the effect of anæsthetics in first stimulating and then depressing is that of the plant *Mimosa pudica*. Claude Bernard demonstrated that this reacts to an anæsthetic just as an animal does ; chloroform or ether affects it as do other stimuli, causing its leaves to undergo an orderly series of movements. If the action of the anæsthetic is prolonged, the plant passes into a non-irritable phase. This anæsthesia passes away gradually, the plant returning to its normal irritable condition. If, though, the anæsthetic is not withdrawn after a certain time, death instead of recovery ensues. Anæsthesia can be induced by mechanical shock, by cold, by the electric current, by some neutral salts, and by many organic chemical compounds.

Anæsthesia is essentially a **diminution or an abolition of the normal responsiveness to stimuli**. Life itself may be regarded as a series of stimuli and the responses thereto, and it is from this point of view that the study of anæsthesia has such wide biological interest. Anæsthesia appears less in fact as an artificial process

[1] *Trans. Society of Anæsthetists*, Vol. 8, p. 47.

than as a phenomenon closely related to normal processes of life such as sleep and the termination of life—death. Its similarity to these two phenomena is as true as it is apparent. Sleep is a temporary condition of loss of responsiveness, what the physiologists speak of as a "reversible inhibition"; death is an inhibition that cannot be reversed. Anæsthesia, too, is a reversible inhibition, but we all know by how narrow a margin it is separated from irreversibility.

Inhibitions play a large part in the normal processes of organic life.[1] Thus, as Sherrington has shown, motor neurones innervating any group of muscles become inexcitable during the activity of the antagonist groups; they are inhibited. Various activities, vasomotor, cardiac, muscular, are subject to various forms of inhibition. Many of these normal inhibitions are due to chemical substances present in the blood. Probably they are of the same essential nature as anæsthesia, another inhibition due to the circulation in the blood of chemical bodies with particular properties. Responsiveness, the decrease of which is anæsthesia, is largely a matter of metabolic condition. Lillie[2] points out that, in common with most vital activities, it is subject to inhibition or enhancement in accordance with physiological requirements. He draws an interesting parallel between the repletion of feeding and anæsthesia. Animals become sluggish and irresponsive when well fed, and show heightened activity when deprived of food. Automatic motor activity and the responsiveness to the stimuli of food-substances—the physiological condition expressed in consciousness as hunger—are increased when the supply of energy-yielding material is depleted. "Hydra, one of the primitive metazoa, shows restless, swaying movements when hungry, which increase the radius swept by its tentacles. These organs respond promptly to the contact of food particles, which are captured and conveyed to the mouth. When well fed, the creature is quiescent and the tentacles indifferent to such contact; they are, as it were, anæsthetised. Such an instance illustrates the regulatory *rôle* which fluctuations in the responsiveness of an animal to stimuli play in its normal life. Similar variations in neuromuscular responsiveness occur throughout the animal kingdom. This is well illustrated by sleep, which is, in fact, a physiological narcosis. From such facts we must conclude that the essential basis of anæsthesia is to be sought not in purely artificial modifications of nervous irritability, but in some normal or physiological modification which is capable of being intensified and prolonged by the use of certain physical and chemical agencies.

[1] *American Year Book of Anæsthesia*, 1915, pp. 1 *et seq.*
[2] *Ibid*, p. 2.

These are the various anæsthetising agents, such as the electric current, cold, or narcotising substances."

If, as the above facts suggest, anæsthesia is a reversible decrease of irritability, we must, in order to understand its essential nature, have a clear conception of the essential nature of irritability. What is the physico-chemical basis of this property, and in what way is it influenced by anæsthetics? We have seen that plants and lower animals exhibit increased irritability under the early influence of anæsthetics, as human beings evince excitement or intoxication when affected by alcohol or small doses of ether or chloroform. Automatic rhythmical activity, as of cilia, spermatozoa, or the heart beat, is very generally heightened in weak solutions of alcohol and other narcotics. It is lessened by stronger solutions. Vernon states that weak solutions of narcotics increase the consumption of oxygen in isolated tissues [1]; stronger solutions produce the opposite effect. Are we to assume that anæsthesia is a purely chemical process consisting in a lowered oxidation of the affected tissues? Snow, indeed, held that the process of anæsthesia was perfectly demonstrated by the waning of a taper alight in a bottle through which chloroform vapour was diffused. The general view that narcosis is essentially a phenomenon of retarded oxidation was suggested by Claude Bernard.[2] It is true that decrease in oxidation is frequently observed during narcosis. The bulk of evidence goes to show, however, that this decrease is a **consequence of paralysis of metabolic and other functions and not itself the primary condition.** There are great similarities between the physiological behaviour of asphyxiated and that of narcotized tissues and cells. There are also differences showing that the two processes are not identical. Thus there are numerous instances of typical anæsthesia unaccompanied by any decrease in oxidation. The activity of organisms and of tissues may be profoundly inhibited by anæsthetics while the rate of oxidation is unaltered or only slightly decreased. Cell division in developing eggs supplies one of the clearest examples. In solutions of various anæsthetics of concentration sufficient to prevent cleavage entirely the rate of oxidation was only slightly decreased. Yet oxidation may be very much more greatly decreased by lowering the temperature without any arrest of cleavage. The slight decrease of oxidation, therefore, accompanying anæsthesia cannot stand in any causal relation to the process. Further, the insensitivity of cells and tissues to simple abstraction of oxygen is in contrast to their sensitivity to

[1] *Journal of Physiol.*, 1912, Vol. 5, p. 197.
[2] "Leçons sur les Phenomènes de la Vie," Claude Bernard, 1879, T. 1, p. 276.

anæsthetics. Thus nerve trunks only gradually lose irritability and conductivity in an oxygen-free atmosphere, but the desensitizing effects of anæsthesia are rapid and complete.[1] Recovery is different, too, in the two cases, being very much more rapid after anæsthesia. Similar examples are afforded by the behaviour of cilia and of protoplasm in plant cells. The reflex irritability of the frog's isolated spinal cord may be entirely lost under anæsthesia without the general oxidation rate of the tissue being affected. The narcotized cord differs from the non-narcotized in this, that the latter shows increased oxygen consumption if stimulated, but during complete narcosis no such effect is seen. Oxygen is essential for the normal irritability of the cord ; complete recovery from narcosis requires not only removal of the anæsthetic, but also the presence of free oxygen. There may, however, be partial recovery even in the absence of oxygen. These facts show how important oxygen is to the normal activity of the nerve cell, but they also show that, given a free supply of oxygen, the consumption in the normal resting cord may be the same as in the narcotized cord. If narcosis were simply asphyxia such a result would be inexplicable. Again, after narcosis lasting for days irritability returns promptly on the removal of the anæsthetic.[2] There is no evidence that nerve cells can survive a lack of oxygen for any such time. Tissue oxidation appears to be directly influenced only by relatively high concentrations of anæsthetics, and this tallies with clinical experience. A direct suppression of intracellular oxidation is probably not the essential basis of anæsthesia. This condition depends probably not on any alteration of purely chemical conditions, but on some influence exercised by the anæsthetic on the living substance in which the chemical processes take place (R. S. Lillie). Can we discern the nature of this influence ? We have shown reasons for belief that, although lowered oxidation is a usual accompaniment, it is not the essential feature of anæsthesia. Some experimenters have claimed to find this in a **combination between the anæsthetic and the protoplasm of the cell.** Moore and Roaf[3] concluded that anæsthetics form unstable compounds with the proteids of the tissue cells and that anæsthesia is due to paralysis of the chemical activities of the protoplasm resulting from such combination. They found that, at a certain concentration of anæsthetic, precipitation occurs in the cellular proteid and that with the combination of the anæsthetic and the proteid there occurs a splitting off of electrolytes. There is some relationship between

[1] *Journal Biol. Chem.*, 1913, Vol. 14, p. 517.
[2] *Biochem. Zeitschr.*, 1914, Vol. 61, p. 81.
[3] *Proc. Royal Soc.*, Vol. 77, Series B, No. B. 515, p. 86.

the electric current and anæsthesia. The constant current produces in many irritable tissues effects closely resembling true anæsthesia. The essential basis of the effect appears to be an altered electrical polarization of the cell surface. The electrical conductivity of cells appears to be decreased during narcosis (Lillie). This decrease is due to decreased permeability of the plasma membrane. It appears highly probable that lipoid-solvent anæsthetics—and the chief anæsthetics are lipoid-solvent—cause their effects through a purely physical change in the cell system, particularly in the plasma membrane. Lillie attributes great importance to this alteration of permeability in the enclosing membrane of cells. He says: "Anæsthetic action is due primarily to a modification of the plasma membrane of the cells or irritable elements of such a kind as to render these membranes more resistant towards agencies which under usual conditions rapidly increase their permeability; cytolysis and stimulation, both of which depend on such increase of permeability, are hence checked or prevented. Decrease in the readiness with which permeability is increased thus involves for an irritable tissue decreased irritability (anæsthesia). . . . The state of the lipoids in the plasma membrane largely determines the readiness with which changes of permeability—and of the dependent electrical polarisation—are induced by external agencies. Slight permeation of the lipoids with a lipoid-solvent . . . increases irritability; more lipoid-solvent renders a change of permeability difficult, hence the anæsthetic action; while concentrated solutions of lipoid-solvent disrupt the membrane and produce irreversible alterations in the cells. It is the membrane-change with the associated variation of electrical polarisation which appears to be the primary physiological event in stimulation"; probably, therefore, also in its antithesis, anæsthesia. Other physiologists have ascribed to the lipoid elements of protoplasm a still more preponderating part in the causation of anæsthesia. Meyer and Overton believe that it is upon the lipoids of the brain cells that anæsthetics exert their action, forming a chemical combination which destroys the functioning power of the cells. According to these observers it is the solution of the narcotic in the lipoid which determines anæsthetic action. It has been shown that during anæsthesia the amount of lipoid, particularly lecithin, in the blood is greatly increased, the presumption being that it has been dissolved out of the brain. Moreover, it was shown by experiments (Nerking) that a much greater quantity of anæsthetic was needed to overcome animals that had been previously dosed with lecithin than was needed for those that had not been thus prepared. Bibra and Harles similarly attempt to explain the

action of anæsthetics by the fact that all anæsthetic substances, whether alcohols, aldehydes, ketones or ethers, possess the common property of depressing the central nervous system, which is rich in fat-like constituents. These anæsthetic bodies are solvents of ordinary fat, and it is assumed that they remove fat-like bodies from the brain cells. In the same way they dissolve lecithin, the fatty constituent of blood cells. On this theory anæsthesia is thus explained: "Narcotising substances enter into loose physico-chemical combination with lipoids, perhaps lecithin, in cells of nerve tissues, and in so doing change their normal relationship to other cell constituents, through which change results an inhibition of the entire cell chemism. Narcosis disappears as soon as the loose combination dependent on solution tension breaks up." [1] It is well known that acidosis and formation of acetone frequently accompany anæsthesia This is explained, by those who hold the lipoid theory, through the splitting up of fats and lipoids which is presumed to occur. Traube [2] has shown that effects similar to narcosis are seen in cases where lipoid solubility can play no part. His theory of anæsthesia makes it depend upon the surface activity of the narcotic. The ready penetration of narcotics into living cells he attributes not to lipoid solubility, but to low solution affinity in relation to the medium bathing the cell. Traube's views, in spite of the elaborate care with which they are evolved, hardly bear the destructive criticism put on them by the work of Hans Meyer,[3] who showed that experiments with altering temperatures greatly favoured the idea that lipoid solubility rather than surface-activity determines anæsthetic action. Lastly, mention must be made of Crile's view that anæsthesia is a phenomenon of acidity.[4] This observer has shown by numerous experiments, both clinical and of the laboratory, that the acidity of blood, as determined by its H-ion concentration, is increased by inhalation anæsthetics. Ether, nitrous oxide, and alcohol all produce an acidity of the blood which is apparently proportional to the depth of anæsthesia. Crile points out that one of the most remarkable effects of an anæsthetic is increase in force and rapidity of respiration. The more the voluntary muscles are paralysed the more is the respiratory centre stimulated. This centre has been evolved, he says, to act with increase of vigour proportional within certain limits to H-ion concentration, whereas the centres governing the voluntary muscles are inhibited by the same condition. Thus the driving

[1] *American Year Book of Anæsthesia*, 1915.
[2] "Theorie der Narkose," *Pflüger's Archiv.*, 1913, Vol. 153.
[3] *Arch. f. Experim. Path. u. Pharm.*, Vol. 28, p. 239.
[4] "Surg. Gyn. and Obstet.," Vol. 20, pp. 680 *et seq.*

force of the brain, which produces acidity by activating the muscles, is diminished by intake of anæsthetics, and the state of unconsciousness or anæsthesia is reached. The respiratory action, by which CO_2 is eliminated and oxygen supplied, is at the same time increased. "It is probable that the remarkable phenomenon of anæsthesia—the coincident existence of unconsciousness and life—is due to this antithetic action of the cortex and the medulla under the influence of acidity." In support of his argument Crile states that during anæsthesia acidity waxes and wanes with deeper and lighter narcosis and vigorous or less vigorous breathing, according as the supply of oxygen is diminished or increased.

Considering the experimental and clinical facts hitherto brought to light and the theories founded upon them, we may summarize our ideas of anæsthesia by stating that it appears to depend upon an **alteration in the nerve cells, both in their enclosing membranes and internal structure.** This alteration is of a physico-chemical kind, and is accompanied by lowered oxidation, by an altered electrical state, and by a decreased alkalinity. It is a change which depends upon the presence of the anæsthetic agent and disappears after this has been removed. It is not yet clear whether this change is brought about by the anæsthetic itself, or by an altered state of the blood induced in that fluid by the anæsthetic which is carried in the blood to the cells.

CHAPTER III

PHYSICAL AND CHEMICAL NATURE OF GENERAL ANÆSTHETICS

ANÆSTHETIC agents do not belong to any one chemical class. They differ from one another both in physical qualities and in chemical composition. Thus nitrous oxide is under ordinary atmospheric pressure and temperature a gas, ethyl chloride a highly volatile liquid, chloroform and ether liquids of less ready evaporation. There are also solids, such as chloral and hedonal, capable of producing anæsthesia. Yet there is a tendency for narcotic properties to belong to all compounds chemically akin to ether and chloroform.[1] It was said, indeed, of Snow that in consequence of his numerous experiments with various chemical bodies of this nature, if he were given the boiling point and chemical composition he could foretell the narcotic properties of the given compound, or whether it would be devoid of any. It must be remembered that chemically we are inaccurate when we speak of the effects of chloroform, ether, etc. We are talking of their vapours, and these have no existence ordinarily except mixed with air. Thus when we talk of chloroform, for example, we mean a mixture of chloroform vapour with varying amounts of air. Since we cannot chemically classify anæsthetics in one group, it is desirable to have some other standard by which we determine whether a body may be regarded as a general anæsthetic or not. This standard is the therapeutic. We place them by their effects, not by their composition.

We regard a body as a general anæsthetic if it has these qualifications :

(1) It produces insensibility when introduced into human beings, and also paralysis of muscles ;
(2) It produces its effects in such a way that they can be controlled both as to rapidity and as to depth ;
(3) It is capable of complete elimination when administration ceases and when eliminated leaves the organism undamaged ;
(4) Its entry into the organism is unaccompanied by harmful disturbance or great discomfort ;
(5) It is conveniently carried and administered ;
(6) Its action within the body can be safely maintained for considerable periods of time.

[1] *Journal Amer. Med. Assoc.*, Jan. 20, 1906, p. 167.

All anæsthetics do not possess these qualities to the same degree. Thus, for instance, we shall find that chloroform answers to the demand of (3) much less satisfactorily than does nitrous oxide, but as regards (1) it is clearly the superior. Any body, however, that complies with these six conditions may be regarded as a general anæsthetic, a better or a worse, according to the more or less completeness of its compliance. Many gases are anæsthetics, but they are inconvenient to use because they are gases. Even the best of them, nitrous oxide, suffers to some degree from this physical characteristic. Hydrogen and nitrogen can produce unconsciousness by the simple exclusion of oxygen from the body. Their mode of action prevents them from answering to (6), and they cannot be regarded as general anæsthetics. Other gases which have been used for anæsthesia, but have proved inferior to the common agents, are methyl chloride (CH_3Cl), ethylene (C_2H_4) and methyl oxide $(CH_3)_2O$. Highly volatile liquids are represented by ethyl chloride and ethyl bromide, the former a good anæsthetic within certain limits, and aldehyde ($CH_3 . CHO$). Slightly denser bodies are ether $(C_2H_5)_2O$, ethyl bromide (C_2H_5Br), and amylene (C_5H_{10}). The latter produces insensibility rapidly. Sir Benjamin Richardson showed its doubtful value as an anæsthetic, and Snow abandoned it in spite of the ease with which its vapour, free from pungency, can be inhaled. A full account of its preparation and use is to be found in his book. Methylene (CH_2Cl_2) has been widely used. The liquid is, however, probably a mixture of chloroform and methylic alcohol.[1] Acetate of methyl ($CH_5CO . OCH_3$) and acetone ($CH_3 . CO . CH_3$) are anæsthetics of poor quality, and carbon bisulphide (CS_2), also an anæsthetic, is a powerful poison.[2] Ethidene dichloride (CH_3CHCl_2), also called ethylidene chloride, chloridene, chlorinated muriatic ether, has a boiling point almost identical with that of chloroform, and its effects are similar. It is obtained pure only with difficulty.[3] Ethylene chloride (Dutch liquid) ($CH_2Cl . CH_2Cl$), a colourless, oily liquid much resembling chloroform, gives an irritating vapour. Other bodies of about an equal degree of volatility with the former which produce anæsthesia are acetate of ethyl ($CH_3CO . OC_2H_5$), tetrachloride of carbon (CCl_4), amyl hydride (C_5H_{12}), ethyl nitrate ($C_2H_5 . NO_3$), benzene (C_6H_6), and turpentine ($C_{10}H_{16}$). Alcohol (C_2H_6O) is capable of producing anæsthesia when taken in sufficient quantity, and use has been made of this property by the administration of large doses of brandy before operation in the absence of any better anæsthetic. Bromoform (tribromomethane),

[1] Hewitt's "Anæsthetics," 1912, p. 474.
[2] "Anæsthesia": Gwathmey, 1914, p. 720, and p. 717.
[3] Snow, "On Anæsthetics," p. 421.

suggested by Nunneley in 1849, produces rapid narcosis when inhaled, but its use is attended with great danger.[1]

The chief solid bodies which are capable of producing anæsthesia when introduced into the circulation are chloral ($CCl_3 . CHO$) and hedonal ($C_6H_{13}O_2N$). Their dangers, as we shall see, outweigh their advantages. Benzoic ether ($C_6H_5CO . OC_2H_5$), ethyl benzoate, and acetal ($CH_3CH . (OC_2H_5)_2$) belong to this class. Amyl chloride ($C_5H_{11}Cl$) was stated by Richardson to produce an anæsthesia too slow and profound for ordinary practice. This was accompanied by great lowering of the temperature of the body.

We may now state in more detail the chemical and physical facts relating to the commonly used general anæsthetics. These will be dealt with in the order of their importance from this point of view. Chloroform, on which the earliest and the greatest amount of scientific experiment has been expended, heads the list.

Chloroform

Chloroform appears to have been made for the first time in the same year (1831) by three different individuals, Liebig and Soubeiran in Europe and Guthrie in America, and each was apparently unaware of the others' achievement. Later, in 1834, its chemical composition was determined by Dumas. It has the formula $CHCl_3$, and is also known as perchloride of formyl, trichlormethane or dichlorinated chloride of methyl. It is a clear, volatile liquid with burning taste and sweetish, sickly smell. Chloroform is made by distilling ethyl alcohol with bleaching powder (calcium hypochlorite) in the presence of slaked lime (calcium hydrate). Besides ethyl alcohol chloroform is made from methylated spirit and from acetone. When obtained pure the product is, of course, the same from whatever source it comes, but according to the source, so are the impurities which have to be removed, and the less impure the source the greater the ease with which pure chloroform is obtained. Absolutely pure chloroform is very unstable and rapidly decomposes even in darkness. It has specific gravity of 1·5, and boils at 61·5° C. Such a liquid is unsuitable for practical purposes, and chloroform as we use it is always pure chloroform to which absolute alcohol has been added in small amount, reducing the specific gravity to about 1·480. According to the British Pharmacopœia (1898) specific gravity should be not less than 1·490 nor more than 1·495, and the boiling point should not be below 60° C. Messrs. Duncan and Flockhart describe their chloroform as having specific gravity

[1] "Anæsthesia" Gwathmey, 1914, p. 720, and p. 717.

of approximately 1·485, and they point out that minute traces of water have considerable effect in altering the boiling point, so that it may be even lower than 60° C. This is due to the formation of compounds between chloroform, alcohol, and water, and chloroform and alcohol. Anæsthetic chloroform contains about 2 per cent. of alcohol. The liquid prepared from ethylic alcohol requires less rectification than that prepared from methylated spirit or acetone. It is generally understood to contain a very minute proportion of ethyl chloride, the result of the action of bleaching powder on alcohol. This ethyl chloride is absent from chloroform prepared from acetone. Worth Hale[1] shows that two classes of impurities are found in chloroform :—

(1) Those coming from the process of manufacture ;

(2) Oxidation products of pure chloroform and of alcohol.

The former include excess water and alcohol, acetone, methyl alcohol, carbon tetrachloride, aldehydes, chloral, ether, higher alcohols, ethyl and ethylene chloride, and others. All these are tested for before a chloroform is labelled "for anæsthetic purposes" by any good maker, and they may be disregarded. It is decomposition products (class 2) only that are ever to be found in good brands of chloroform. These are **acetaldehyde, acetic and formic acids, carbonyl chloride and hydrochloric acid.** According to Waller purified chloroform is itself more toxic than the concentrated impurities. Experiments between old and fresh chloroform showed no demonstrable difference in toxicity estimated by the time taken to kill mice. **The efficacy of alcohol in preventing the decomposition of chloroform** was shown by Squibb in 1857, who kept chloroform with ·625 per cent. of ethylic alcohol for ten years without a trace of decomposition. The *rôle* of alcohol in thus preserving chloroform has been variously explained. Some authorities (Adrian, Schacht and Biltz) believe that chloroform is itself decomposed in the presence of alcohol, but that the latter acts by forming harmless products with the chlorine liberated and thus renders decomposition innocuous. Baskerville and Hamor,[2] on the other hand, maintain that the preservative action of alcohol is due to the inhibiting effect which it has upon the oxidation of chloroform. All compounds which are soluble in chloroform and readily oxidizable have this effect. All such preservatives are reducing agents, and the effect is due to their capacity for oxidation. When chloroform is preserved with alcohol, the preservative is gradually consumed and eventually totally destroyed, after which decomposition of the chloroform proceeds. It is obvious from the foregoing that decomposition

[1] *Archives Internat. Med.*, Vol. 15, 1915, p. 945.

[2] *Journal of Indust. and Engin. Chemistry*, 1912, Vol. 4, p. 362.

of ordinary chloroform during keeping is unlikely. To be on the safe side, however, chloroform should be kept in red or yellow glass-stoppered bottles in a cool dark place. Similarly, if chloroform is transported, care is necessary to avoid much agitation or exposure to light. It has been shown [1] that when anæsthetic chloroform is subjected to agitation accompanied by mechanical shock the alcohol present undergoes oxidation to an extent depending upon the violence and length of the agitation and the amount of air present. If unprotected cork stoppers are used, decomposition products may be formed also from extraction of resinous matters from the stopper. Falk has attempted to show that chemical changes are produced in chloroform by the passage of a current of oxygen. If such were the fact, it would have important bearings on practice. Baskerville and Hamor, however, testing the process under conditions usual in practice, find no evidence of such decomposition. They bubbled oxygen through four ounces of chloroform for ten and a half hours, at the end of which time three-quarters of an ounce of liquid remained. Testing this, they found no free chlorine or hydrochloric acid and a faint reaction for odorous and chlorinated decomposition products. Acetic acid was present, and a pronounced reaction with sulphuric acid test. Passing the gases through water showed that oxidation products of alcohol (from the alcohol in the chloroform) were not carried over with the oxygen, but that they were concentrated in the residue. It may be mentioned *à propos* of this question that Willcox and Collingwood recommend oxygen bubbled through absolute alcohol as a strong cardiac stimulant; and, in accordance with their suggestion, I have many times sent oxygen through alcohol and chloroform in maintaining anæsthesia during operation upon very feeble or collapsed subjects. Whether chloroform is decomposed after it enters the circulation is a physiological question which will be discussed later. Chloroform from methylated spirit contains a number of impurities not found in that from ethylic alcohol, but by sufficient purification it can be made satisfactory for anæsthesia. Similarly chloroform from acetone contains bodies not present either in ethylic or in methylated chloroform, and more complicated processes of purification are necessary. The chloroform in common use from good manufacturers has undergone these various purification processes, and the well-known brands are satisfactory whether they are ethylic, methylated, or acetone chloroform. Hewitt circularized fifty-three anæsthetists in order to discover their practice and opinion with regard to the three kinds of chloroform. He found that some preferred one kind, some another, and he

[1] *Journal of Indust. and Engin. Chemistry*, 1912, Vol. 4, p. 362.

adhered "to the belief that, when properly prepared and purified, the actions and after-effects of these three kinds of chloroform are indistinguishable." With this I am in agreement, and have on several occasions been able to test on the same patient at different times first ethylic and then methylated chloroform without discovering the slightest difference. Acetone chloroform is often held to be weaker in its action than the other two. This tallies with my own experience. The addition of 0·25 per cent. of ethyl chloride, however, is said to render it physiologically identical with alcohol chloroform.[1] It is useful in practice to have an easy and fairly accurate *test of the purity of chloroform.* This is given us, fortunately, as Snow pointed out, by its smell. The smell of chloroform is peculiar and is closely resembled only by that of Dutch liquid, and of chlorinated products of hydrochloric ether. These bodies are much more difficult to prepare than chloroform, and are unlikely to be offered in its place. The only article that can be mixed with chloroform without altering its appearance and smell is alcohol. Chloroform should be perfectly transparent and colourless and have an odour which is not irritating. A second easy test is to evaporate 20 c.c. from a large piece of filter paper on a warm plate. There should remain no residue possessing any smell except that of chloroform. A more accurate method is to evaporate 100 c.c. slowly over a water bath until 10 c.c. remain. This should be colourless and without foreign odour. Other tests are:

(1) Shaken with sulphuric acid, chloroform should give no yellow or brown coloration;
(2) 20 c.c. chloroform mixed with 15 c.c. concentrated sulphuric acid in a glass-stoppered tube of 50 c.c. capacity, which has been rinsed with concentrated sulphuric acid, gives no coloration after the addition of 0·4 c.c. of pure 40 per cent. formaldehyde solution, even if shaken for five minutes (test for higher alcohols);[2]
(3) Tested with litmus, there must be no acid reaction;
(4) No precipitate should be formed with solution of silver nitrate (test for hydrochloric acid); other acids may be tested for by elaborate processes for which a chemical work should be consulted;
(5) Carbonyl chloride can be tested for by Ramsay's barium hydroxide reaction, a white film at the junction of the liquids;
(6) The chlorine is detected by 10 per cent. solution of cadmium and potassium iodide. There should be a negative result;

[1] *Trans. Society of Anæsthetists*, Vol. 7, p. 89.
[2] *Journal of Indust. and Engin. Chemistry*, 1912, Vol. 4, p. 362.

(7) Ether, if present in chloroform, may be detected by dropping into the liquid a watery solution of iodine. If the drops turn deep red, ether is present. Crystals of nitrosodic sulphide of iron are insoluble in pure chloroform, but dissolve if ether is present ;

(8) Methyl compounds present in chloroform may be shown by the black colour formed when the liquid is treated with concentrated sulphuric acid.

Chlorinated decomposition products are likely only in chloroform that has been stored for a long time under conditions conducive to oxidation. They are easily formed, however, when chloroform is in use if there is an open flame or gas jet burning. The irritating fumes of carbonyl chloride (phosgene gas) formed in this way, or by the presence of an oil or gas stove in a small, ill-ventilated room where chloroform is being given, cause smarting of the eyes and coughing and burning sensations about the throat and chest. More serious results, such as bronchitis or broncho-pneumonia, may affect a patient exposed for a long period of time to the inhalation of carbonyl chloride. If ever, therefore, conditions of lighting or heating necessitate the possibility of the formation of phosgene gas, attention must be given to the ventilation of the room so that the carbonyl chloride may be blown away as it forms.

Experimental proof of the formation of carbonyl chloride when chloroform vapour comes into contact with the flame or the products of illuminating gas may be found in the *Archives de Med. et de Pharm. Mil.*, Vol. 63, 1914, p. 225.

Liquid chloroform has a blistering effect if applied to the skin, and if allowed to reach the air passages or the eye the consequences may be fatal or locally destructive. The vapour when inhaled with air, as, of course, it always is under ordinary conditions, has no irritating effect upon normal air passages. The vapour of chloroform is more than four times as heavy as air, a fact for which the anæsthetist has cause for gratitude, since if it were not so he would inhale a far greater proportion than he actually does in the course of a long administration. The quantity of vapour that the air will hold in solution at different temperatures depends on the elastic force of the vapour at those temperatures.[1] Snow determined the quantity of vapour of chloroform that 100 cubic inches of air will take up and retain at various temperatures from 40° to 90° F. At the lowest degree the amount was 7 cubic inches, and at the highest 55 cubic inches. Since the effect of chloroform depends upon the quantity present in the air breathed, it is easy

[1] Snow, "On Anæsthetics," p. 421.

to see the importance of atmospheric temperature, the amount of chloroform volatilized and retained in the air being so much higher in a warm than in a cool atmosphere. It is notorious that patients are more easily brought under the influence of chloroform in such places as India than in cooler climates. At the same time the evaporation of chloroform causes a certain amount of latent heat, and the vapour breathed by the patient is to this extent cooled. The percentage composition of mixtures of air and chloroform vapour can be determined by the densimetric method introduced by Waller and Geets [1]; or if the chloroform of the mixture is not less than 3 or more than 12 per cent., it can be absorbed by olive oil and thus determined.[2] It is reckoned that the vapour of a drop of chloroform, when inhaled with an ordinary inspiration of air (*i.e.*, 400 to 500 c.c.), gives a 1 per cent. mixture of chloroform and air.

Chloroform can mix with alcohol, ether, and other organic liquids. It is soluble in about 288 times its own volume of water. Chloroform vapour is not inflammable, but is decomposed if passed into a lighted spirit-lamp. A smoky flame results, emitting fumes of hydrochloric acid.[3]

Ether

Ether, or ethyl oxide, $(C_2H_5)_2O$, is made from the distillation of alcohol with sulphuric acid. Other names for it are accordingly vinous ether, ethylic ether, and sulphuric ether. It is a clear, colourless, very volatile liquid with burning taste and penetrating smell. As it is so volatile, and as its vapour is explosive when mixed with air, great care is necessary when ether is poured out or administered in the presence of an open fire or a flame. For the same reasons, it is not used in the proximity of a cautery or of diathermy application. Striking examples of these dangers have been related at the Anæsthetic Section of the Royal Society of Medicine in London.[4] In one case the small lamp of a direct vision laryngoscope, inserted into the mouth of a patient who had taken open ether and was at the moment inhaling warm ether vapour and oxygen, caused an outburst of flame which filled the mouth and its immediate neighbourhood. In another instance open ether was being used in a small room heated by a gas fire. This fire was in the anæsthetist's estimation quite 6 feet away from the patient. At the close of the operation, for gangrenous appendix, about 6 ounces of ether were poured

[1] *Brit. Med. Journal*, 1903, June 20, p. 1421.
[2] *Ibid.*, July 12, 1902.
[3] Hewitt, "Anæsthetics," 1912, p. 26.
[4] *Proc. Roy. Soc. Med.* (Anæsthetic Section), Vol. 14, No. 7.

into the abdominal cavity. Almost at once a column of blue flame leapt from the abdomen, and in another moment a second column from the mask over the patient's mouth. Apparently ether vapour, with which the small room was well charged, ignited near the gas stove, and the flame rushed to the vicinity of the table. In yet a third case a violent explosion was caused by the use of a diathermy instrument in the neighbourhood of an atmosphere of nitrous oxide, oxygen and ether. It is notable that in none of these cases did any but trivial damage follow the accident. The flame of ether burns out so rapidly. The explosion, however, may be most alarming. Water has little effect on burning ether unless the whole fabric alight is submerged. Otherwise water displaces the ether, carrying the flame about. The ether vapour tends to cling to surfaces and travels in this manner. Ether is manufactured both from ethyl alcohol and from methylated spirit. As is the case with chloroform, the liquid obtained from ethyl alcohol is much more expensive than the other, but again the effects of the two, when both are from trustworthy manufacturers, are exactly alike. After long use of only ethyl ether at St. George's Hospital we have now for several years confined ourselves to the methylated variety, and have been unable to detect any difference in clinical results.

Ether prepared from ethylic alcohol consists entirely of diethyl ether, and has a boiling point of 35° C. and specific gravity ·720. When prepared from industrial spirit, the methyl alcohol present produces di-methyl ether and methyl ethyl ether. The di-methyl ether is a gas, and mostly passes away. The methyl ethyl ether boils at 11° C., and the presence of this in methylated ether lowers the boiling point and to a slight extent the specific gravity. The boiling point is from 26° to 35° C., and the specific gravity from ·715 to ·720. It is quite possible, Messrs. Duncan and Flockhart inform me, to prepare from methylated spirit an ether which answers the tests for ether prepared only from ethylic alcohol. In this case the lower boiling point fractions are passed on and condensed separately, leaving the higher boiling point portion, ethylic ether itself, to come on later. Ether vapour is more than twice as heavy as air, having a specific gravity of 2·565. It burns with a white, luminous flame, and, as previously mentioned, explodes if mixed with air in the neighbourhood of flame. Ether for anæsthetic purposes, however prepared, should be of specific gravity not more than ·722 nor less than ·720. It must be neutral to test paper and must evaporate without leaving any residue. It should form a clear mixture with oil of copaiba in any proportion. The common impurities are water and alcohol; in any small amounts these are not deleterious. Traces of

aldehyde are often present. Embley has pointed out that with age ethyl ether acquires acetaldehyde and methyl ether formaldehyde in greater amounts the longer the ether is kept. The United States Pharmacopœia regards ether for anæsthesia as having from 2·5 to 4·5 per cent. of alcohol and a little water. A method for the determination of small amounts of alcohol and water in ether for anæsthesia is described by Mallinckrodt and Alt.[1] Ether does not keep so well as chloroform, and if in a bottle only partly filled may become decomposed into acetic acid and water. The anæsthetist, therefore, should keep it in small bottles soon used up, and not exposed to strong light. Baskerville [2] has investigated the changes which occur in ether badly stored. Exposed to varying temperature or sunlight, or kept in colourless glass bottles or badly-stoppered containers, ether undergoes slow combustion. The stages of the process appear to be:

(1) Formation of hydrogen peroxide from water and oxygen of the air;

(2) A direct oxidizing action resulting in formation of acetaldehyde, acetic peroxide and eventually acetic acid.

Ether which has been exposed to air and light for some time acquires a peculiar pungent odour due to hydrogen peroxide and aldehyde. These substances may irritate the lungs if inhaled, and ether that smells of them is not fit for anæsthetic purposes.

Ether has no blistering effect upon the skin. Evaporated there it causes merely a feeling of intense cold. It has led to intense conjunctivitis when allowed to remain in contact with the eye, owing to material covering the eyes during an operation being gradually soaked with the liquid. Dropped into the eye for a moment, ether has proved harmless.

Water is soluble in ether, which can retain one-tenth of its volume of the liquid. The quantity of ether vapour which air will hold at different temperatures was estimated by Snow as ranging from 52 cubic inches (to 100 cubic inches of air) at 50° F. to 138 cubic inches at 70° F.

It has been asserted that pure di-ethyl ether by itself cannot produce anæsthesia, but merely drunkenness and peripheral congestion.[3] According to this view commercial ether owes its anæsthetic power to ethylene and possibly other analgesics. A liquid made of pure ether and ethylene was found to have anæsthetic properties, and it is held that by controlling the amounts of ethylene in such a fluid it is possible to control analgesia

[1] *Journal of Industr. and Engin. Chem.*, 1916, p. 807.
[2] *Ibid.*, Vol. 3, Nos. 5 and 6.
[3] *Amer. Journal Surg.*, Vol. 33, No. 4, p. 35 (Supplement).

without producing unconsciousness. Cotton[1] has asserted, indeed, that commercial ether owes its properties to its impurities, viz. :

(1) Irritative impurities, aldehydes and ketones ;
(2) Anæsthetic impurities, carbon dioxide and ethylene ;
(3) Toxic impurities, carbon monoxide and peroxides.

A pure condition of insensibility to pain, without the intoxication of ordinary ether narcosis, should be obtainable, according to such a view, by the use of an ether which retained only the anæsthetising impurities of the liquid ordinarily supplied. Chemically pure ether Cotton found to be a poor anæsthetic. Nine to fourteen ounces failed to produce real anæsthesia. There were persistent muscular tremor, peripheral congestion, a high pulse rate, and post-anæsthetic nausea.[2] Small amounts of carbon dioxide added relieved tremor and spasm and allowed anæsthesia to develop.

There are five kinds of ether commercially available in Great Britain. Two of these only are to be used for general anæsthesia. These are :

(1) *Ether purus* (off.), also called *ether purissimus, ether pro narcosi.* This is the official British Pharmacopœia pure ether for general anæsthesia. It is made from pure alcohol, has specific gravity not above ·722 nor below ·720. It is described by the United States Pharmacopœia as 96 per cent. by weight of ethyl oxide.
(2) *Rectified ether,* specific gravity ·720, made from methylated spirit.

The other varieties are :

(3) Ether (off.) made from pure alcohol, containing not less than 92 per cent. ethyl oxide, the remainder being alcohol and water. This is ordinary medicinal ether.
(4) Absolute ether, methylated, specific gravity ·717 to ·719, adapted for spraying.
(5) Methylated ether, specific gravity ·730, used for common purposes, ice machines, etc.

The last two are both made from methylated spirit.

Ethanesal,[3] introduced as a new general anæsthetic by Mackenzie Wallis and Langton Hewer, consists of pure ether, prepared in a particular way, which holds in solution ketones, carbon dioxide, and ethylene. Wallis found that to obtain a perfectly pure ether the chief difficulty lay in getting rid of the mercaptans. By distilling ether with very finely divided permanganate oxidation of these impurities occurred, and with the use of a special reflux condenser all the mercaptans were retained in the residue. Ether

[1] *Lancet,* 1905, Vol. 2, p. 1631.
[2] *Medical Annual,* 1919, p. 66.
[3] *Lancet,* June 4, 1921, p. 1173.

so treated is quite free from aldehydes and mercaptans, containing only traces of alcohol, water and peroxides. To remove these the distilled product is treated with anhydrous copper sulphate. It was found that ether distilled in this way with permanganate and with copper sulphate had greatly increased power of absorbing gases (carbon dioxide and ethylene) compared with this power in good ether before the distillation. The resulting liquid had good anæsthetic properties. Investigation showed that certain ketones in the ether were largely responsible for the anæsthetic properties. Good ethers treated with finely divided permanganate yielded a pleasant-smelling residue which contained ketones. "The residue appeared to be the essential element in the production of a good and safe anæsthetic. The mixture of ketones proved to be very potent, and a volatile solvent was necessary. In view of the readiness with which ordinary ether can be purified, this compound was selected as the solvent. Into this pure ether the mixed ketones were placed in varying proportions, and the mixtures so obtained were found to be capable of producing anæsthesia. The anæsthetic action was enhanced if the mixed ketones were first treated with carbon dioxide and ethylene" (Wallis). Thus it appears that ethanesal differs from Cotton process ether in the presence of ketones and the power they confer of holding larger quantities of carbon dioxide and ethylene in solution. The ketones used comprise those in the middle of the series, and a loose chemical combination between these substances and the carbon dioxide and ethylene apparently results. The *Lancet*[1] report on ethanesal states that this anæsthetic has the physical properties of ether. It is anhydrous, free from sulphur compounds, and has a neutral reaction. It contains a very small amount of a substance oxidized to acetaldehyde by chromic acid, which presumably is ethylic alcohol. It begins to boil at 33·0° C. When fractionated

41 per cent.	distilled	over	between 33·9°	and	35·0° C.
13	,,	,,	,, 35·0°	,,	36·1° C.
16	,,	,,	,, 36·1°	,,	37·8° C.
28	,,	,,	,, 37·8°	,,	40·2° C.
2	,,	,,	above 40·2° C.		

Ethanesal is a mixture of substances having a boiling point not far removed from that of ether.

Ethyl Chloride

Ethyl chloride, C_2H_5Cl, is made from ethyl alcohol and hydrochloric acid. When used for general anæsthesia it should

[1] *Lancet*, June 18, 1921, p. 1309.

be free from water, foreign chloride, acids, aldehydes, ether and alcohol. The brands obtainable in London were shown to be of this necessary purity when tested.[1] Ethyl chloride is a colourless, highly volatile liquid with an aromatic smell and a sweetish taste. Owing to its extreme volatility, it is supplied in hermetically sealed glass tubes fitted with a tap, pressure on which releases the liquid in a fine spray. These tubes must be labelled "for general anæsthesia" to distinguish them from those containing less pure ethyl chloride, which is employed for local anæsthesia by freezing. Ethyl chloride is inflammable, burning with a smoky, green-edged flame, producing fumes of hydrochloric acid. It must, therefore, not be used near a flame or cautery. It may even decompose when near a hot bulb or incandescent light. The specific gravity of ethyl chloride is 0·9214 at 0° C., and the density of its vapour 2·219 times that of air. The boiling point is 12·5° C. It is very soluble in alcohol, and when so dissolved may be kept in closely stoppered bottles. Ethyl chloride for general anæsthesia should leave no residue on evaporation, and should give no acid reaction with litmus paper. Impurities do not readily form in it except in the presence of oxygen. Water will dissolve about one-fiftieth of its weight of ethyl chloride, acquiring a sweetish ethereal taste.

Nitrous Oxide

Nitrous oxide, N_2O, known also as laughing gas, protoxide of nitrogen, or nitrogen monoxide, is obtained from ammonium nitrate. It has a specific gravity of 1·527. It is a stable, colourless, transparent gas with a faint, peculiar sweetish smell and taste. In practice the smell is generally obliterated by that of the rubber face piece through which the gas is inhaled. If a burning body is placed in nitrous oxide it continues to burn, the gas being decomposed. Without great heat it is not easily split up. Water at 0° C. dissolves little more than its own volume of nitrous oxide, the solubility diminishing as the temperature of the water is raised.

Since the transport of large amounts of a gas would be hopelessly inconvenient, nitrous oxide is provided for practical purposes in liquid form. Liquefaction takes place under a pressure of 30 atmospheres at 0° C. or 50 atmospheres at 7° C. (Hewitt). The liquid is colourless, mobile, and very lowly refractive, with a density of 0·937 at 0° C. It may be preserved indefinitely in steel cylinders with good valves. Such cylinders of various sizes are provided by the makers. Convenient sizes for private practice are those containing 15 ounces of the liquid, which provide about

[1] *Lancet*, 1905, Vol. 2, p. 1631.

50 gallons of the gas. Smaller cylinders to give 25 gallons of gas are also useful for private work, and larger cylinders to give 100 gallons are commonly employed in hospital. Superficial solidification in the form of a compact snow may be produced by the intense cold resulting from the conversion of the liquid nitrous oxide into gas. This occurring at the outlet of a cylinder may block the valve. Such solidification will not occur if the cylinder is in the vertical position, or if the valve is kept warm by a small spirit lamp. Both these devices are adopted in the latest forms of apparatus for administering nitrous oxide gas. The gas for anæsthesia should consist of at least 95 per cent. of pure nitrous oxide. Other oxides of nitrogen and chlorine are sometimes present as impurities. If in any but minute proportions, these would give the gas an irritating quality which is absent from pure nitrous oxide. They may be detected by passing a slow stream of the gas through a cold solution of ferrous sulphate and of silver nitrate. No precipitate should be produced in the former and no brown or black coloration in the latter. In America, where some hospitals manufacture their own nitrous oxide, much attention has been paid to its pharmacology; for further information the reader is referred to "The Modern Hospital," 1915, p. 175; to the *Journal of Laboratory of Clinical Medicine*, 1915–16; and to an article on a "Method of Analysing Nitrous Oxide," by Boothby and Sandeford (*American Journal of Physiology*, 1916, p. 376).

Baskerville and Stevenson [1] conducted an examination of the gas supplied on the American market, and describe a new method for the quantitative determination of nitrous oxide. They conclude that nitrous oxide for anæsthesia should contain at least 95 per cent. of nitrous oxide, no solids, liquids or combustible organic matter, and no chlorine or other oxides of nitrogen than the monoxide.

At the Lakeside Hospital, where nitrous oxide was manufactured on the premises, certain symptoms led to suspicion as to the purity of the gas.[1] After entirely removing nitric oxide by confining the gas in iron tanks or over water for a few hours an improvement was observed. A thorough washing with sulphuric acid was further added to the manufacturing process, in order to remove ammonia, a likely impurity.[2] The gas was now found to be strictly neutral instead of slightly alkaline, and the results of administration became uniformly favourable. It may be mentioned here that differences have been observed between nitrous oxide obtained from the liquid gas in cylinders

[1] *Journal of Industr. and Engin. Chem.*, 1911, Vol. 3, p. 579.
[2] *Journal Amer. Med. Assoc.*, Vol. 65, 1915, p. 1973.

and that which has been never liquefied, as in some hospital installations. The latter gas suffers some admixture of air, whereas that liberated straight from a cylinder is free from this.

Ethyl Bromide

Ethyl bromide, C_2H_5Br, is made from sulphuric acid, bromide of potassium, and ethyl alcohol or industrial spirit. The methyl bromide present in the crude article from industrial spirit is easily eliminated, and the finished drug has a boiling point of 39° C. and specific gravity 1·47 at 15° C. Its odour rather resembles that of chloroform, and should have no garlic flavour. It is a transparent, colourless, and highly volatile liquid. Its vapour density is 3·754 (Marchland). Ethyl bromide mixes with alcohol and with ether, but is not easily dissolved in water. Ethyl bromide deteriorates rapidly if kept long. It must be protected from light, and a bottle or tube once opened should not be used again. When exposed to air for some time it decomposes with liberation of bromine. Common impurities that may be present in ethyl bromide are bromine, hydrobromic acid, phosphoretted hydrogen, amyl and ethylene compounds and sulphur compounds.[1] The drug for anæsthesia should evaporate without residue, give no acid reaction, and not alter on addition of silver nitrate.

Hedonal

Hedonal has been used extensively for the production of anæsthesia by intravenous infusion, but has fallen into disfavour, as we shall see later. This body is made from the secondary methyl-propyl-carbinol by heating it with urea nitrate under pressure. It is a derivative of urethane, with the chemical formula $C_6H_{13}O_2N$, and is a white crystalline powder with faint aromatic odour and taste. It melts at 74° C. and boils at 215° C. Hedonal dissolves in 120 parts of water at 37° C., but is more soluble at higher temperatures, and is readily soluble in alcohol, ether, chloroform, and other organic solvents. When boiled with alkalies it is split up into its constituents. It is incompatible with alkalies, their carbonates, and bicarbonates.

The above-described bodies, or mixtures containing some of them in various proportions, are the only agents in common use for the production of general anæsthesia. Other anæsthetics which have been employed in the past are ethidene dichloride and amylene or pental.

Ethidene dichloride, ethylidene chloride, or dichlorethane,

[1] Hewitt, "Anæsthetics," 1912, p. 33.

$C_2H_4Cl_2$, is a transparent, colourless liquid resembling chloroform in taste and smell. It has the specific gravity of 1·178 at 15° C. and boils at 58·60° C. (Gwathmey). It is a metamer of Dutch liquid, ethylene dichloride, from which it is distinguished by its much lower boiling point and by its not being affected by cold alcoholic potash, which decomposes Dutch liquid. In Clover's day the ethidene dichloride supplied for anæsthesia could be divided by fractional distillation into two or more substances (Hewitt). According to Sir Benjamin Richardson, the quantity needed for anæsthesia was 2 to 8 drachms, and the strength of vapour 5 to 10 per cent. Anæsthesia was produced more rapidly than with chloroform and frequently with much spasm. Probably this agent is well adapted only to short operations, and for them is inferior to ethyl chloride and nitrous oxide.

Amylene, or pental, or trimethyl ethylene, C_5H_{10}, was regarded by Snow as being a mixture of several isomeric bodies. It is a colourless, thin, very volatile liquid with specific gravity of about ·6544 at 10° C. Richardson found that a 15 per cent. vapour was needed for anæsthesia, which was rapidly induced. The vapour is described as disagreeable, though not pungent, and like that of wood spirit. The vapour of amylene is inflammable. The boiling point of amylene is constant only when it is in the form of pure iso-amylene. This boils at 38° C. Nering (1887) introduced the pure body by the name of pental.

Other bodies which have been used to produce anæsthesia are *ethylene* (olefiant gas), *amyl hydride, amyl chloride,* and *ethyl nitrate. Turpentine* and *benzene* in vapour form can produce anæsthesia, as also can *carbon tetrachloride.* These bodies have, however, demonstrated their power more by accident than design, as they are not good anæsthetics, and knowledge of their quality in this respect is more valuable for avoiding misfortune in factories and shops than for producing anæsthesia in surgery.

Methyl oxide, $(CH_3)_2O$, is a gas with which anæsthesia has been produced. It has a specific gravity of 1·617. The late Sir Frederic Hewitt carried out with it some clinical experiments in which the present writer participated. The results obtained were much inferior to those commonly seen with nitrous oxide. The patients were, generally speaking, either insufficiently narcotized when a dilute vapour was used, or after satisfactory anæsthesia with a strong vapour suffered from sickness. A strong vapour, which alone produced good anæsthesia, was, moreover, unpleasant to inhale.[1] A vapour of at least 25 per cent. is needed for narcosis.

Methylene chloride, CH_2Cl_2, also called dichlormethane, methylene, methylene bichloride, or methene chloride, is a

[1] *Lancet*, Nov. 19, 1904, p. 1408.

colourless liquid made from alcohol and chloroform by the action of zinc and hydrochloric acid. It has a specific gravity of 1·377 at 15° C. and boiling point of 40° C. Introduced by Richardson in 1867, methylene chloride has never been fully established as an anæsthetic, chiefly, no doubt, owing to the number of fatalities that have attended its use.[1] Moreover, it has been held on good evidence that "methylene" is not an individual drug, but a mechanical mixture of chloroform and alcohol.

Scopolamine, $C_{17}H_{21}NO_4HBr3H_2O$, the hydrobromide of an alkaloid obtained from the *Solenaceæ*, is sometimes used for producing general anæsthesia by hypodermic injection.[2] More often it is employed merely as a preliminary to inhalation and to spinal anæsthesia. It is chemically identical with hyoscine. When pure, scopolamine or hyoscine is a syrupy liquid. The hydrobromide forms colourless, transparent rhombic crystals, having an acrid, slightly bitter taste. It is soluble in 1·5 parts of water, 16 of alcohol, 750 of chloroform. The water solution is slightly acid to litmus.

Paraldehyde, the polymeric form of acetaldehyde, has been used in 5 per cent. solution for producing anæsthesia by intravenous infusion.[3] *Isopral* similarly used has been stated to possess advantages over hedonal in the same circumstances.[4]

Another quite different body, *magnesium sulphate*, has also been shown capable of producing anæsthesia when injected into the veins. From experience with its use in the treatment of tetanus Peck and Meltzer concluded that human beings were more susceptible than animals to the effects of this salt, and clinical experiment corroborated their view. Magnesium sulphate cannot be reckoned, however, as an anæsthetic of proved value for ordinary purposes. Recently Gwathmey has employed injections of 300 c.c. of 4 per cent. magnesium sulphate in association with morphia as a preliminary to colonic or inhalation anæsthesia.

[1] Gwathmey, 1914, p. 777.
[2] *Medical Annual*, 1918, p. 95, and *Journ. Amer. Med. Assoc.*, 1916, ii. 1131.
[3] *Lancet*, Nov. 2, 1912, p. 1220.
[4] *Munch. Med. Woch.*, 1911, p. 778.

CHAPTER IV

PHYSIOLOGICAL ACTION OF ANÆSTHETICS

In order to employ anæsthetics to the best advantage we should have knowledge of their action, not merely as we see it clinically, but also in its more secret effects as it has been found out by experiment. We wish to know how the drugs we employ gain access to the tissues on which they work, what, if any, effects they produce on the blood in which they travel, and how they affect all the tissues and organs and functions of the body while they are present in the circulation. Further, we must see how they are eliminated and what are the consequences of their passage. Ultimately narcosis in animals occurs, as we have seen, owing to the effect upon the structure of the nerve cells. The anæsthetic can be brought into contact with this structure only by means of the fluid with which the cells of the whole body are bathed. In the lowest forms of life anæsthetics are simply absorbed from the surface, and even cold-blooded animals, such as the frog, can be narcotized if a part of the body is kept immersed in chloroform water. In human beings sufficient absorption from the surface is not possible. There are, however, several routes by which the anæsthetic may reach the blood stream. It may be injected directly into a vein, or it may be inhaled as a vapour and enter the circulation by way of the air-cells of the lungs ; it may be injected into muscles or under the skin, and thus enter the capillaries, or it may be swallowed by the mouth or absorbed from the rectum. In practice inhalation is the most commonly used method—firstly, because the very wide surface for absorption offered by the lung alveoli permits of a rapid intake of anæsthetics and of almost equally rapid elimination ; the anæsthetic, moreover, enters the circulation at a situation from which it is rapidly brought into contact with its desired object, the brain. Secondly, some anæsthetics being naturally gases or extremely volatile liquids, they can only be administered by inhalation.

Inhaled anæsthetic vapours produce no visible local effects upon the air passages before they enter the alveoli of the lung. Some irritation of the larynx and upper air passages may, however, be caused, as is shown by coughing or retching that sometimes

accompanies the beginning of inhalation. The spasm, swelling, and congestion of the fauces and the secretion of mucus and saliva which often arise in the early stages of narcosis are not produced mainly by the local effect of the vapour, but by the anæsthetic after it has entered the circulation. Local effect, nevertheless, is partly responsible for these symptoms, for they are much less evident when ether, for instance, is given *per rectum* than when it is inhaled. These symptoms are of much practical importance, as they interfere with the unobstructed entry of air and the anæsthetic, and since they are not much seen in the laboratory, where anæsthetics are commonly administered through a tube in the trachea, cutting off the fauces and larynx, they have received scant attention from physiologists. Practical anæsthetists, however, following Hewitt, have laid great stress on this common prevalence of obstruction in the upper air passages and the necessity for obviating it, however it arises.

We shall see later that very many of the difficulties that occur in practice are due to this tendency for local obstruction to appear, and we shall find that the obstruction may be caused, not solely by the action of the anæsthetic, but also reflexly by the procedures of the surgeon. In other directions, too, we shall note that the operation in progress influences the behaviour of the anæsthetized patient, and that it is often hard to distinguish between the effects that are being produced by the surgeon and those that are due to the anæsthetic. In discussing the physiological effects of anæsthetics, therefore, we must bear in mind that these are very different when they are the sole effects concerned and when they are complicated by concurrent operation. The former condition was described by Hewitt as *simple*, the latter as *complex* anæsthesia. Broadly speaking, we may say that in treating of the physiology of our subject we shall be dealing with simple, and in all the practical parts with complex, anæsthesia.

Besides the actual operation other factors influence complex anæsthesia, for example, alterations in the position of the subject, diminution in oxygen supply, and exposure; these, too, will be considered. The most serious surgical effects complicating anæsthesia are those that are comprised in the term shock. These are similar to the effects that accompany any deep narcosis without operation, and it is plain that the differentiation of the two when present together may be well-nigh impossible. In many of the fatal cases that occur in practice the deaths are due to the combined effect of shock and narcosis. Shock in its relation to anæsthesia will be discussed in a later chapter. In describing the physiological action of anæsthetics it is important to bear in mind that, however little individual peculiarities may play a part in the phenomena of

the laboratory, there is no doubt of their influence on the behaviour of human patients. No little part of an anæsthetist's success, we shall discover, is due to his perceiving and understanding the physical and the mental nature of the patients with whom he deals. Experience teaches him that the same anæsthetic administered in the same way produces its effects on different persons in a manner accompanied by very different symptoms. These differences we shall attempt to define and explain in the clinical chapters following. Idiosyncrasy, however, plays some part even in the laboratory. Exactly on what it depends we do not know, and the word is used merely to express the fact that animals apparently exactly alike, in weight, etc., do not always react in exactly the same manner to identical anæsthetic treatment.

When anæsthetics are inhaled into the lungs and absorbed into the blood, they visit every region of the body and influence, it may be supposed, every organ. This influence is, however, much more easily detected in some directions than in others. It is the apparently selective action of these substances upon the nervous tissue of the body that gives them their especial value. They influence the most highly developed portions of the nervous system soonest and most profoundly. The reason and the will and the power of co-ordinating impressions and movements succumb before the special senses, and these before consciousness. Thus it is sometimes possible to maintain a condition in which, though conscious, a patient is insensitive to pain. Touch and smell and sight are lost before hearing. The last appears, indeed, to be accentuated for a short time as the other special senses disappear. On recovery again hearing is the first sense to return. The fact that a state arises in which pain is imperceptible although consciousness is not lost was explained by Snow as due to the local action of the anæsthetic upon the peripheral nerves. These are still influenced by the chloroform present in the contents of the lymphatics, whereas the brain has no lymphatics, and so escapes sooner from the action of the anæsthetic when it is no longer inhaled. On the other hand, Claude Bernard proved experimentally that the sensory centres of the cerebro-spinal axis are first affected and that the sensibility of sensory nerves is destroyed, not by the local action of anæsthetics, but by action upon the centres.

The subjective sensations of people taking anæsthetics suggest an early influence on the sensory nerves, whether direct or from the sensory centres, for tingling and feelings of warmth and of numbness are frequently experienced in the early stage of induction.

At the beginning of their action anæsthetics **stimulate** the

organism. They belong to those substances which are correctly described, as Snow insisted, as narcotico-irritants; they are not purely narcotics. Thus the respiration and the pulse are at first quickened, depending probably upon stimulation of the respiratory and cardiac centres, and the higher portions of the brain are excited. Ideas flow rapidly and may be shown by talking or, as control disappears, by excited muscular movements when consciousness has gone. The cerebral cortex is affected first, the cerebellum and basic ganglia next, then the sensory and then the motor tracts and centres in the cord. Lastly, the bulbar seat of control of respiration and circulation is overpowered if the dosage is pushed thus far. The spinal cord and the peripheral nerves are less affected than the brain. It was shown by Claude Bernard that the sensory centres are primarily and chiefly affected, and that sensory nerve endings lose their sensibility because of paralysis of their centres, not from the local action of the drug on the nerve endings. He showed, however, that just as with failing nutrition nerves die from the periphery upwards, so under anæsthetics function fails first in the nerve endings, then in the trunks of the nerves, and lastly in the roots. There is still much that we do not know about the action of anæsthetics on the nervous system. Anæsthetists are aware that the reaction of individuals to anæsthetics differs even after complete abolition of what is ordinarily called consciousness. It is not merely that, consciousness abolished, the autonomic system acts uncontrolled and reflex phenomena appear in response to stimulus. To some extent this takes place before the reflex centres are themselves affected. Yet besides these reflex phenomena, which appear with greater ease and in fuller vigour in some subjects than in others, there are symptoms which indicate the differences in what we may call nerve constitution, for want of a better term. This quality persists and has influence after the abolition of gross consciousness. It is as though some subconscious mentality existed and acted in anæsthesia after gross consciousness has been abolished. The individual is unconscious according to the ordinary meaning of the word, but he has a consciousness of a kind. In neurasthenics, in people who have been recently through nerve-shattering experiences, and in others of what we call a highly strung nature, phenomena occur both in the form of reflex movements and cries and in the form of unusual variations of pulse and breathing which are not witnessed during anæsthesia in the ordinary or the phlegmatic individual. Alcoholics and infants show similar phenomena. Probably the causation is different in the different kinds of individual. In all of them we seem to see an activity and irritability of the autonomic system

out of the ordinary. Dr. Dudley Buxton[1] suggests that in such persons we have an unusual persistence of subconscious mentality. Along with this persists an "awareness" of the autonomic system. He brings into this explanation of the phenomena which we are considering the dreams that sometimes occur during narcosis. These may be vividly impressed upon the mind of the patient and yet may be impossible of recollection in the waking state. When anæsthesia is again entered upon on another occasion the same dream recurs or is even logically continued from where it ended during the former experience. These dreams are much more common, or at any rate much more often realized, with nitrous oxide than with the more powerful anæsthetics, and there is no doubt a relation between the depth of narcosis and their occurrence. Probably in full anæsthesia these subconscious phenomena do not arise, but in some individuals this full anæsthesia is reached with much more than usual difficulty. It is the possible occurrence of these dreams, with their sometimes terrifying nature, that makes it highly undesirable to allow operation to continue except during full anæsthesia. It is a familiar fact that a state of analgesia during which no pain is felt, but during which consciousness is present, often precedes full awakening from nitrous oxide, and may arise also under other anæsthetics. During this analgesia the subconsciousness postulated by Dudley Buxton is active and may receive terrifying impressions that may even live vaguely during full consciousness, or at least be revived if anæsthetics are taken again. Many individuals are given a horror of "gas" by the vague persistence of impressions due to operation continued during analgesia after full unconsciousness has lifted. Such persons may have a revived horror each night just as sleep overtakes them.

The *muscles* themselves may be thrown into violent contractions during narcosis, usually of a tonic character. When clonos occurs it is due to anoxæmia or the stimulation of a reflex. Some *muscular spasm* is an almost constant accompaniment of the induction of anæsthesia. It varies greatly in amount, both according to the muscular development of the individual and according to the method by which the anæsthetic is being given. The feebler the individual the less the liability to spasm, and, generally speaking, the greater the air-deprivation involved in the administration the greater the spasm. Also, generally, the more gradually an anæsthetic is given the less is the muscular excitement. The different anæsthetics vary also in their tendency to evoke spasm. Just as the first nervous excitement is followed by complete unconsciousness, so the

[1] *Lancet*, Jan. 1, 1921.

muscular system after its period of stimulation passes in anæsthesia into a state of relaxation. Whether the muscular phenomena are due to direct action of the anæsthetic on the muscles or are only secondary to that upon the nerves supplying the muscles cannot be stated with certainty. Voluntary muscles are much more affected than the involuntary. Unstriped muscle may to some extent lose its tone, but it appears to undergo none of the complete relaxation commonly seen in the voluntary muscles. Thus, for instance, in dilating the cervix uteri an amount of spasm has often to be overcome which cannot be diminished by the anæsthetist, however profound a narcosis he produces. Moreover, the alimentary canal is often under observation during anæsthesia, and it is plain that the muscular coats of the bowel and of the stomach do not noticeably contract or relax as a rule. Their tone is abolished, but this absence of contraction is probably due to reflex sympathetic stimulation from the incision, and not to direct anæsthetic action. Relaxation of the sphincters both of rectum and of bladder does occur, but it is not a common occurrence. Usually this action, which is in consciousness partly reflex, is in abeyance during anæsthesia, as are the superficial reflexes generally. During the early stages of narcosis *reflex response* to stimuli is brisk. As narcosis deepens it diminishes and finally disappears as regards most of the reflexes, but not as regards them all. A test of the depth of narcosis is thus afforded and is of practical use in the case of reflexes that are easily accessible. The eye offers this opportunity especially well, and the absence of conjunctival reflex and later of corneal reflex is constantly made use of as a sign of the depth to which narcosis is present. The patellar reflex often persists ; Dastre found it constantly present in animals during ether anæsthesia. The reflex alterations of respiration that accompany stretching of the rectal sphincter or dragging upon organs within the pelvis or abdomen, prostate and uterus, for instance, may, on the other hand, persist even when narcosis is pushed to the deepest degree compatible with safety. Individuals vary both in the order and in the completeness with which their reflexes go.

The *respiratory centre* is sensitive to many stimuli in the course of operation, both those arising directly from the inhaled vapour and those which come as reflexes from the operation itself. We shall have to note these in the clinical chapters, and here need only say that, generally speaking, respiration varies in character according to the greater or less oxygen deprivation and according to the sensitiveness of the part of the body undergoing operation.

The *glandular tissues* of the body are affected in various ways by anæsthetics, and differently by different agents. Thus the

salivary, sweat and mucous glands secrete more freely throughout ether anæsthesia, while the kidneys barely secrete at all. The matter will be dealt with in more detail in connection with the separate anæsthetics.

Snow divided the effects produced by chloroform into five stages, and as it has been customary ever since to speak of the **stages or degrees of anæsthesia,** it is convenient to recognize this broad classification of effects. At the same time it must be borne in mind that with modern methods many symptoms of these stages are more often than not imperceptible ; and the passage from normal wakefulness to complete anæsthesia is a quiet, gradual process in which the descent from one degree of narcosis into another is unmarked by any sudden or striking phenomenon.

The *first stage* is from the beginning of the induction till consciousness is lost. It is marked subjectively by rapid flow of ideas while control and volition disappear. The pallor and dryness of fear may accompany the first inhalations. There may be pleasant or unpleasant sensations and dreams accompanied by laughter, sobbing, or talking. In the latter case a phrase is often repeated over and over again, gradually fading into a half-finished or imperfectly articulated sentence. In the same way a movement of hand or foot may be rhythmically repeated. The reflexes are active, and stimuli are responded to by purposive movements—*e.g.*, if the skin of the thigh is pinched, the limb will be drawn up. The pupil is dilated, the pulse quickened, and the breathing deeper and faster than before. It may be interrupted by swallowing movements or by coughing or retching. In this stage there may be insensibility to pain.

The *second stage* begins with loss of consciousness and ends with the disappearance of many reflexes. It is characterized by muscular spasm and excitement. The face is flushed. There are often sitting-up movements, waving of arms and legs, spasm of the jaw muscles. There may be loud cries or rapid mumblings, but there are no properly articulated words. Increase of saliva and mucus may lead to spitting and coughing. The pupils are smaller, the pulse and breathing are still more rapid than normal, but the latter is much interrupted by spasm, which may affect the vocal cords and the respiratory muscles.

The *third stage* is that of anæsthesia proper. It is distinguished by relaxation of muscles and abolition of reflexes. The conjunctival reflex goes early and the corneal later ; the pharyngeal, laryngeal, and skin reflexes are also abolished. The spasmodic, laboured, noisy, excited breathing of the last stage is succeeded by regular calm, automatic respiration, loud only if the stertor

of paralysed palate and tongue is allowed to persist. The pupils are larger again, and the pulse slower and less forcible, being about normal in force and frequency. The colour of the face begins to fade. There is a fall in the temperature of the body.

If narcosis is further deepened, the *fourth stage* is entered upon, and is shown by widely dilated pupils, pallor of skin, sweating, and progressive feebleness of pulse and of breathing. The rectal and bladder sphincters relax. Muscular tone and blood pressure fall, till, in what corresponds to Snow's *fifth degree* of chloroform narcosis, the globes of the eye roll back behind slightly parted lids, the respiration becomes irregular and feeble and ceases, to be followed a little later by stoppage of the fluttering heart and death.

Both chloroform and ether cause a *lowering* of the body *temperature,* and this is greater the more complete is the relaxation of the muscular system.

CHAPTER V

PHYSIOLOGICAL ACTION OF ANÆSTHETICS SEPARATELY CONSIDERED

Chloroform

We may now pass on to consider in detail the effects that accompany the entrance into the body of the commonly employed anæsthetics. The greater part of our knowledge has been derived from the study of chloroform, with which, therefore, we begin. *Locally applied,* chloroform irritates and blisters the skin. *Injected beneath the skin,* it produces local anæsthetic effects, its action on the tissues being too destructive to allow much absorption into the circulation. *Injected into an artery,* it renders the limb or the whole body rigid. This rigidity remains for weeks in the dead body, and would probably be permanent if the chloroform were prevented from evaporating (Snow). If muscles thus rendered "chloroform-rigid" are examined microscopically, cloudy changes are seen in the fibres. *Injected into a vein* in sufficiently dilute solution, chloroform produces anæsthesia. Leonard Hill showed that if 1·5 minims were injected into the jugular vein and washed in with saline fluid a brief stimulating effect on the heart was produced, followed by a weakening of the beat, and that if 5 minims were used dilatation of the organ and weakness of the beat followed immediately. The *swallowing* of chloroform in considerable quantities has led to fatal results. Hewitt refers to a case in which after 2 ounces had been taken death ensued from syncope during the act of retching, and to another in which unconsciousness persisted for eighteen hours, but life was saved by protracted artificial respiration. There was no attempt at breathing for fifteen minutes.

Chloroform *vapour,* as we have seen, does not exist alone, but only mixed with air. It can exist alone only in a temperature of 140° F. or more, or if the atmospheric pressure is removed (Snow). The extent to which it is mixed with air depends in practice both upon the methods employed for its administration and upon outward circumstances, of which the temperature of the room is the most important. We shall see that in those methods of giving chloroform which depend upon the use of a

machine which regulates the strength of the vapour supplied accessory circumstances, such as room temperature, have little influence. In the simpler methods, when chloroform vapour is inhaled from an open mask on which the liquid evaporates, the influence of temperature is such that the mixture breathed will vary from 4 to 9·5 per cent. of chloroform, for instance, according as the temperature is 50° or 70° F. The maximum strength of vapour which could be inhaled with safety was held by Snow to be 5 per cent. of chloroform to 95 per cent. of air. Lister in later years made many investigations of the vapour provided by the simple methods of chloroform administration then in vogue. He maintained that from a folded towel on which a surface about the size of a hand's palm was moistened an atmosphere containing about 4·8 per cent. of chloroform was inhaled if it was held fairly close to the face. Lister pointed out that the larger the surface from which the liquid was evaporating the higher was the chloroform percentage in the vapour, and this led him to recommend a smaller mask, such as that provided by drawing the end of a towel through a safety-pin. From such a mask he reckoned that the vapour commonly supplied contained about 1·5 per cent. of chloroform.

More recent investigations of the atmosphere inhaled from open masks and from apparatus have been carried out by Waller, Legge Symes, and Goodman Levy. The former, with Wells, tested various apparatus for the dosimetric administration of chloroform, and found that the Dubois, the Junker and the Vernon Harcourt all supply pretty accurately the percentages which they declare. Waller and Wells made important observations on chloroform dropping. The drop of chloroform from an average pipette or from a stoppered bottle they estimate as 20 to 25 mgrs., supplying 4 to 5 c.c. of vapour. Thus a drop inhaled with an ordinary inspiration (400 to 500 c.c.) supplies a 1 per cent. mixture. For ordinary anæsthesia of the human subject Waller considered that the vapour inspired should be between the limits of 1 to 2 per cent. chloroform. The experiments of Symes,[1] who weighed the atmosphere aspirated from beneath a Skinner's mask, showed that at ordinary room temperatures and with moderate quantities of chloroform a vapour was supplied of fairly uniform concentration at the desired strength of 1 to 2 per cent. The concentration reached 3 to 4 per cent. when chloroform was copiously supplied, and this rises quickly to dangerous strengths, such as 10 per cent., if the mask is closely applied to the face. Better results followed dropping than douching. Fall in the frequency and depth of breathing led to inhalation of dangerously concen-

[1] *Lancet*, July 9, 1904, p. 81.

trated vapour, even when the amount of chloroform was not apparently excessive. Open fabrics, such as domette, yielded higher percentages than closer materials, such as flannel. Levy [1] demonstrated the effect which the warmth of the expired air has in preventing the cooling which accompanies evaporation of chloroform; this "discounts to a great extent the supposed importance of the effect of the temperature of the external air." His practical conclusion was that a required anæsthetic effect may be perfectly maintained in spite of temperature variations, provided that definite and small quantities of chloroform be applied at definite intervals of respiration. When large quantities of chloroform are being evaporated a prolonged and slow series of temperature changes may result, and will no doubt give rise to varying tensions, which will be sufficiently long continued to induce corresponding anæsthetic effects. Levy investigated the results of employing different fabrics, domette, lint and towelling, from which chloroform was evaporated. He devised a mask in which the cover is divided into different-sized partitions by bands of impervious material, so that by keeping the various divisions wet with chloroform a regulation could be obtained of the vapour provided. The larger, or the smaller, or all the divisions can be kept moist corresponding with the strength of vapour one wishes to employ. The mask is made of domette sewn into a groundwork of Batiste cloth. Another method of regulating the strength of vapour supplied by an open mask and drop bottle is suggested by Levy in the same paper.[1] This consists in dividing the mask into quadrants in imagination, and applying drops to the separate quadrants without letting the moistened surfaces coalesce. Thus two drops are applied to the quadrant; at an interval of six breaths these are increased to five; then a second quadrant is treated in the same way. Ultimately five drops are applied to each of three quadrants every six breaths. With an artificial respiration apparatus Levy found that he obtained a vapour of 3·15, 3·2 and 3·2 per cent. strength at the seventeenth, twenty-third and twenty-eighth respirations respectively; that is to say, when the routine is established a vapour of continuously constant strength is supplied.

The effects produced by chloroform depend entirely upon the amount of it present in the inhaled vapour. Thus it has been shown experimentally [2] that when a low percentage is inhaled an enormous quantity can pass into and out of the body without producing any effect except a fall of temperature. Yet, continued long enough, these weak doses will kill, although anæsthesia

[1] *Brit. Med. Journal*, Aug. 4, 1906.
[2] Buckmaster, *Proceedings Royal Soc. Med.*, Vol. 11, No. 9, p. 16.

has never been produced; the whole metabolism of the body is profoundly affected, and the temperature falls steadily till death. The following table showing these facts is constructed by Buckmaster from experiments carried out on dogs by Paul Bert :—

Percentage of Chloroform Vapour in Air.	Results.	Hours from Commencement of Administration till Death.
0·8	No anæsthesia	9—10
1·2	Diminished sensibility	6—7
1·6	Anæsthesia slowly induced	4
2·0	Anæsthesia in a few minutes	2—3
2·4	,, ,, ,,	1·7
3·0	,, ,, ,,	0·66
4·0	,, ,, ,,	0·5
6·0	,, ,, ,,	0·005

The work of many physiologists, from the time of Snow and of Paul Bert to that of Waller and Buckmaster and Gardner, has determined the amount of chloroform which must be present in the inspired air and in the blood in order to produce anæsthesia, and the amount which, if present, will lead to death. Snow found that 1 grain of chloroform to every 100 cubic inches of air

		Anæsthetic Amount of $CHCl_3$. Milligrams.	Lethal Amount of $CHCl_3$. Milligrams.
Eréhaut and Quinquand (1883)	Dogs.	50	—
Pohl (1890)	,,	18—50	35
Nicloux (1906)	,,	50	41—70
Tissot (1906)	,,	34—40	60—105
Mansion and Tissot	,,	29 32—43	—
Buckmaster and Gardner (1906)	,,	16—31 (reflexes just gone)	61—69
Buckmaster and Gardner (1906)	Cats.	14—27·5 (reflexes just gone)	40

induced his second degree of narcotism; this was a saturation of the air of $\frac{1}{56}$, and the blood of an average adult patient inhaling such a vapour would contain about 12 minims of chloroform. For the arrest of respiration the blood held 36 minims. Paul Bert found that by inhaling the vapour produced by 8 grammes of chloroform to 100 litres of air insensibility was slowly produced in an animal, and it died at the end of four hours of such inhalation.

Buckmaster [1] in his experiments took two points in the narcotic state. The time at which the conjunctival reflex disappeared he regarded as marking the anæsthetic state, and the onset of convulsive respirations the lethal. The table on p. 50, giving milligrams of chloroform in 100 c.c. of blood, shows the results obtained by previous workers as well as by Buckmaster and Gardner.

When the principle had been established that safety in chloroform anæsthesia depends largely upon the proper dilution of the vapour, and that the proper dilution is one which gives a percentage of about 2 per cent., it was inevitable that physiologists should contrive machines which would provide this desired atmosphere. It must be said here parenthetically that overdosage or too strong a vapour is clinically not the only way in which chloroform kills, and that physiology, too, recognizes deaths which occur during inhalation of "physiologically safe" chloroform vapour. The introduction into the laboratory of regulating machines for administration of chloroform has, however, greatly reduced the mortality there. Waller's chloroform balance [2] and Dubois' apparatus [3] are two of the best. These both supply definite percentage mixtures of chloroform vapour and air, the supply being quite independent of the respirations of the animal. Other forms of apparatus, working also on this "plenum" system, are those of Collingwood [4] and of Alcock.[4] The Junker and the Shipway apparatus are similar in type to these in that the evaporation and supply of the chloroform are effected by the apparatus, and not by the patient's breathing; they will be described in detail in the clinical section, as also is the Vernon Harcourt apparatus This is the most prominent example of apparatus which works on the "draw-over" principle. The evaporation and supply of the chloroform are effected by the respirations of the patient. These machines provide a vapour in no case higher than 3·5 per cent. Waller regards the limit of safety as being 2 per cent. It is generally admitted that a stronger vapour may be necessary for induction than need be continued afterwards, and Alcock believed that to induce anæsthesia with his apparatus in the case of an ordinary adult the percentage should reach 2 in two minutes and 2·5 in three minutes; even 3 per cent. was sometimes necessary. Using his apparatus, I sometimes found, as is the case with all regulating machines, that anæsthesia could not be induced within reasonable limits of

[1] *Proceedings Royal Soc. Med.*, Vol. 11, No. 9, p. 20.
[2] *Journal of Physiology*, Vol. 37.
[3] Hewitt's "Anæsthetics," 1912, p. 101.
[4] *Ibid.*, p. 104.

time to the degree necessary for the operation in prospect. Clinically factors are met with which are absent from the subjects of laboratory experiment. These factors, such as the long use of alcoholic drink or other drugs, interfere with the rules laid down in the laboratory. Therefore it must be borne in mind that we have in practice no absolute guide either to safety or to the certainty of satisfactory anæsthesia in the figures determined by the physiologist. These are of the greatest service, nevertheless, as truly representing the principles on which we should work. Moreover, it is quite certain that if we use chloroform in strengths much greater than those determined for us by experiment as being safe we can easily destroy life. It is, however, not so certain that, as some physiologists believe, when chloroform kills it is always by reason of an overdose—that is to say, by the inhalation of too high a percentage vapour. Clinical evidence is against such an explanation as covering all fatalities, and, as we shall see, some physiological evidence also points to other factors than pure overdose playing the chief part in certain instances. One such factor, want of uniformity of administration, may be mentioned here. There is no doubt that it is dangerous to allow the vapour supplied to fluctuate between very low and high percentages of chloroform, at any rate in the early stages of administration. We may suppose now that we have a chloroform vapour of proper dilution being inhaled into the alveoli of the lungs.

Chloroform in the Blood.—From the alveoli it enters the blood. This entrance is effected not merely by the pressure exerted by the vapour. It has been shown not to follow the Dalton-Henry law. The evidence given by the experiments of Moore and Roaf, who measured the vapour pressures of chloroform in water, serum, and hæmoglobin solutions of equal strength to the percentage of this pigment in blood, indicates that the curves of pressures and concentrations in serum and hæmoglobin prove that chloroform cannot be absorbed according to the Dalton-Henry law. These observers found that the proteins of the blood form definite unstable compounds or physical aggregations with chloroform. Buckmaster and Gardner showed that during narcosis arterial blood becomes progressively richer in reduced hæmoglobin, showing that the transport of oxygen by the red corpuscles is interfered with by the presence of chloroform. These authorities further showed that in the blood chloroform is carried almost entirely by the red corpuscles.[1] It does not enter the plasma to any marked extent unless the anæsthesia is extreme or a high percentage vapour is inhaled. They estimated the rate at which chloroform was taken up by the blood, and found that in the

[1] *Proceedings Royal Society*, B., Vol. 79, 1907.

initial stages of induction the chloroform content of the blood rises with great rapidity. During this period, which occupies the first few minutes, the first danger point in anæsthesia occurs because the quantity of chloroform in the blood directly or indirectly affects the respiratory centre in the brain. The respirations then become slower and shallower, and the amount of chloroform in the blood falls, the fall being also due to the exit of the drug from the blood into the tissue-cells of the body.[1] When the animal has passed this first stage the amount of chloroform again quickly rises towards a maximum value, and an equilibrium between the factors which determine the amount of chloroform in the blood appears to be obtained, the processes of intake and output of the anæsthetic at the surface of the lung going on side by side. A state of equilibrium is reached which persists for a considerable period, and throughout this period the difference between the amount of chloroform present in the blood and what is found at the lethal point is very minute. In these experiments the percentage of inspired chloroform was maintained constant, and Buckmaster points out that when the state of equilibrium has been reached anæsthesia can be and should be maintained with a much smaller amount of chloroform vapour than was necessary up to that point. This coincides with the clinical experience that higher percentages are needed for the induction than for the maintenance of anæsthesia. Buckmaster and Gardner found, as have other experimenters, that chloroform is very firmly held by the blood of an anæsthetized animal. At the period when reflexes disappeared they found that 64·3 per cent. of the chloroform was in the red corpuscles. After the inhalation of 2 per cent. chloroform for three-quarters of an hour they found that no less than 98·5 per cent. of the anæsthetic was held by the red corpuscles. In order to prove that the red corpuscles are the essential vehicle for the carriage of chloroform these observers carried out experiments to show that the percentage of chloroform remained constant although the absolute amount in the blood might be modified by abstracting blood from or adding it to an animal. They remark that it may be considered in the highest degree probable that the anæsthetic is associated with the proteins of the corpuscle, but the experiments gave no clue as to whether it is the hæmoglobin or other cell proteins which actually pick up the drug. Some observers—prominent among whom was Nicloux—have maintained that chloroform is decomposed within the body. It has even been maintained that to the hydrochloric acid thus formed are to be attributed the symptoms of acidosis that may accompany or follow inhalations

[1] Hewitt's "Anæsthetics," 1912, p. 20.

of chloroform. The work of Buckmaster and Gardner appears conclusively to prove that no decomposition of chloroform takes place within the body during anæsthesia. They show clearly, in a repetition of the work of Desgrez and Nicloux, the experimental error which led Nicloux to his erroneous conclusion. "The destiny of chloroform in the blood is to be almost entirely exhaled." Only a portion of the chloroform that is inhaled reaches the blood; a certain portion is expired without reaching the alveoli; another portion reaches the alveoli and enters the blood, and of this probably part only is associated with the tissues, the rest being eliminated at the pulmonary epithelium. The assumption by the blood is much more rapid, as we have seen, in the early stages than later, and elimination is less. As anæsthesia goes on the rate of elimination may even exceed that of assumption owing to the increased amount of chloroform in the blood returning to the lungs. The actual amount of chloroform entering the tissues or passing out of the lungs will depend on the mass of chloroform on either side of the pulmonary epithelium.[1] During anæsthesia, of course, intake and output go on side by side, the actual amount present in the body remaining fairly constant when the equilibrium has been reached between the chloroform in the blood and that in the alveoli of the lung.

The *amount of chloroform present in the narcotized animal* has been determined in three ways—

(1) By ascertaining the percentage of chloroform in the blood of animals anæsthetized or killed by chloroform;

(2) By determining the amounts of chloroform in the blood and organs of the body *post mortem*;

(3) By reckoning the difference between the amounts of chloroform in the inspired and expired air.

Waller, whose results were obtained by the use of the densimetric method evolved by Geets and himself,[2] found that in an administration of seven minutes and forty seconds, using a chloroform vapour of 2·7 per cent., a cat inspired 243 c.c. of chloroform.[3] Of this amount 189 c.c. were rejected and 54 c.c. retained. Chloroform was absorbed at the rate of 27 mgrs. per minute. In a further experiment a vapour 14·2 per cent. was used till death in three minutes. The figures then were—inspired chloroform, 284 c.c.; rejected chloroform, 158 c.c.; retained chloroform, 126 c.c., giving a chloroform absorption of 210 mgrs. per minute. Vernon Harcourt [4] found that about one-third of the total amount

[1] *Proceedings Royal Society*, B., Vol. 79, 1907.
[2] *Brit. Med. Journal*, June 20, 1903.
[3] *Lancet*, Nov. 28, 1903.
[4] *Brit. Med. Journal*, July 14, 1906.

of chloroform used was retained at the end of the administration in the case of human beings. This agrees very nearly with Waller's finding. Buckmaster and Gardner have shown that the rate of elimination of chloroform from the body *viâ* the blood is at first comparatively rapid and then slows down. Even the initial rates, however, are much less rapid than the rate of assumption, and on the whole elimination is a much slower process than assumption. These observers state that three-quarters of the chloroform present in the body when inhalation of the drug ceased were eliminated in about half an hour.[1] The extent to which the lungs are being ventilated is the chief, if not the only, factor which determines the rate of elimination. Clinically we notice this in the long time which a patient takes to regain consciousness if he lies quietly sleeping after operation. The same experimenters made important observations on the *blood gases* during anæsthesia. In the first place they proved that, provided the extraction of the blood gases in chloroform anæsthesia is carried out in a perfect vacuum, the *entire quantity of the drug* can be recovered as vapour with the evacuated blood gases.

Buckmaster and Gardner showed that the **fall in oxygen content** of the blood is well marked in anæsthesia. It sinks by 40 per cent.; the hæmoglobin during narcosis, instead of being saturated with oxygen, is so to the extent of 60 per cent. only. Probably this fall in oxygen content is due to direct interference with the oxygen-carrying properties of the red corpuscles, since it is these that are engaged in carrying the chloroform. The darkened colour of arterial blood during narcosis, a familiar feature of chloroform anæsthesia, is thus accounted for. Buckmaster and Gardner further proved that although lung ventilation is diminished about 60 per cent. in the first three minutes of narcosis, and takes place throughout on a lowered level, yet the diminution of oxygen in the blood is due, not to this lowered ventilation, but to the effect of chloroform upon the red corpuscles. This is contrary to the view expressed in the Report of the Chloroform Committee of the British Medical Association in 1910, that the blood retains unimpaired up to death its normal capacity of absorbing oxygen, and that if the amount of this gas diminishes in the blood the decrease is solely due to the slowing of the respirations. We have reason to believe that chloroform is not decomposed in the blood. Is the blood, we may ask, decomposed or affected by the chloroform? Its oxygen-carrying power is much diminished, as we have already found. Many observers have stated that other changes occur of a chemical and physical nature. It has been stated that there is precipitation of hæmoglobin and

[1] *Proc. Royal Soc. Med.* (Anæsthetic Section), Vol. 11, No. 9, p. 21.

of certain proteids of the serum, and the red corpuscles are said to be broken up (hæmolysis). The most recent evidence, however, leads us to believe that none of these phenomena occur when chloroform is used in proper anæsthetic concentration. They can be shown experimentally by prolonged use of a 5 per cent. or stronger vapour. The disintegration of the red blood cells was described long ago, and the evidence for this effect is based upon experiments performed at a time when the importance of accurate percentage of vapour was not fully realised nor the means of achieving it available. Numerous observations have been made upon the behaviour of blood and chloroform *in vitreo*, and it has been shown [1] that low percentages of chloroform slowly kill the blood corpuscles, while high percentages quickly cause laking.[1] Gill thought from his experiments that chloroform took oxygen from the red corpuscles. There appears, however, to be no evidence of any reducing action on the part of the chloroform. It interferes, truly, with the power of the red cells to carry oxygen, but it does not chemically rob them of it. That the chloroform is held tenaciously by the blood all workers on the subject are agreed. Waller, in agreement with Moore and Roaf, believes that it is carried in the form of an unstable chemical compound or physical aggregation with proteids of the blood.

If the blood of animals killed by chloroform be examined microscopically directly after death the corpuscles are seen to have become crenate, and not to collect in rouleaux, as in normal blood.[2] Sansom [3] recorded the effects which chloroform can produce on blood when the two are brought into contact outside the body. He noted corrugation of the cell walls, alteration in shape and coherence of the corpuscles. When liquid chloroform permeates the living walls of blood vessels there is instant stasis of the circulating blood, and this phenomenon was also observed by Lister in the web of the frog's foot when exposed to chloroform vapour. Hamburger and Ewing,[4] in an analysis of the blood changes incident to chloroform anæsthesia, found hæmoglobin reduced, hæmolysis increased, and a slight decrease in coagulation time of the blood, the last most marked from seven to ten days after the inhalation. According to other observers, the coagulation time may be at first shortened by chloroform owing to its action in stimulating the flow of adrenalin from the adrenal glands into the circulation. The matter is complicated and cannot yet be stated positively. Casto [5] sums up experimental evidence by

[1] *Australasian Med. Gazette*, June 6, 1914.
[2] *Trans. Med.-Chirurg. Soc.*, 1864, Vol. 47, p. 337.
[3] *Ibid.*, 1861, p. 372.
[4] *Journal American Med. Assoc.*, 1917, 2, p. 1586.
[5] *American Year Book of Anæsthesia*, 1915, p. 43.

saying: "The effects of chloroform are probably the result of disturbances and consequent interactions between two or more organs which are important in the coagulation process, probably the liver (intestines ?) and adrenal glands." The evidence is not sufficient to prove that a retarding agent is produced. Whipple and Hurwitz [1] show that several hours after administration of large amounts of chloroform to dogs the coagulation time was unchanged; they call attention, however, to the weak consistency of the clot, and believe that failure of the clot to hold firmly rather than a retardation of clotting processes is the cause of post-operative hæmorrhage following inhalation of chloroform. Clinical evidence does not give much help in determining the effect of chloroform on coagulation, for although bleeding appears more commonly after operations done under this anæsthetic than under others, the explanation is that cut vessels may be overlooked during the lowered blood pressure of chloroform anæsthesia and bleed subsequently, whereas the same vessels would be detected and ligatured if ether or nitrous oxide had been the anæsthetic employed. The reaction of the blood, normally neutral, is said by Crile to be increased in acidity during narcosis. This authority finds that the H-ion concentration may be increased to the same extent by chloroform anæsthesia that it is by emotional disturbances, such as fright and anger. Henderson and Haggard hold that there is a reduction of blood bicarbonate during anæsthesia due to over-ventilation; other observers attribute the reduction to metabolic changes. J. B. Collings, from a study of unselected patients, concluded that acidity of the urine is not materially altered, but that it may be decreased if there is hyperpnœa during narcosis.[2]

Effect of Chloroform on the Vascular System.—It has appeared that anæsthetic strengths of chloroform exert little influence on the structure or composition of the blood. Their effect upon the walls of the blood-carrying vessels is equally slight. Experiments made by McKendrick upon the pulmonary circulation of the frog with chloroform vapour showed retardation and ultimate stoppage of circulation in capillaries, arterioles, and finally in pulmonary vessels. Disappearance of the epithelial cells and their nuclei was noted. Capillary vessels became blurred or even disappeared, and the enclosed corpuscles became more or less disintegrated.[3] There appears, however, little reason to believe that like effects follow the use of an ordinary strength of chloroform vapour over a usual space of time. There appears to be little

[1] *American Year Book of Anæsthesia*, 1915, p. 39.
[2] *Brit. Journal Exper. Pathology*, December, 1920, p. 282.
[3] *Brit. Med. Journal*, December, 1880.

evidence of any direct action of chloroform upon the walls of the blood vessels, and this is not surprising, seeing that the muscular tissue of the coats of arteries and arterioles is of the unstriped variety, and on such muscle chloroform has little action compared with that which it exercises on the voluntary muscles. The view is generally held that there is dilatation of the whole cardio-vascular system as a direct result of chloroform action, but proof of this, either experimental or clinical, appears to me lacking. In actual practice the effects of chloroform on the vascular system are so mingled with those of operative procedures, posture, etc., that it is impossible to discern them, and these effects will be best considered with the phenomena of shock. It has been maintained [1] that chloroform has a constrictive action upon the muscular elements of peripheral blood vessels, and this accords with clinical observation when some pallor of the skin is commonly seen even in the absence of lowered blood pressure. Embley and Martin,[2] in a study of the action of chloroform upon the vessels of the bowel and kidneys, found marked dilatation due to the direct effect of the drug on the neuro-muscular mechanism of these vessels.

Effect of Chloroform on the Blood Pressure.—Blood pressure falls under the influence of chloroform. In the earliest stages of inhalation there is a rise, due, according to Gaskell and Shore, to stimulation of the vasomotor centre, but this is replaced by a progressive fall, which is usually noticeable within the first fifteen minutes (McKesson). The behaviour of the blood pressure experimentally is never reproduced in practice where a number of complicating factors come into play, some tending to raise and some to lower the pressure. By itself chloroform produces a steady lowering of pressure, due, in the main, to weakened action of the heart, relaxation of arterioles, and to paralysis of the splanchnic vasomotor mechanism, leading to accumulation of blood within the splanchnic area. The more profound the narcosis the greater is the fall in blood pressure, till in experiments continued till death this appears to occur through the weakened blood pressure being insufficient to supply the vital centres of the medulla. Leonard Hill [3] has shown that in the fully-anæsthetised animal the mechanism is abolished which normally controls the effect of gravity on the blood, and this fact has important bearings on the moving of patients and their position under anæsthetics. Hill showed that when the body of an animal which is under chloroform is changed from the horizontal to the vertical a much greater fall of blood pressure occurs than in the normal animal.

[1] *Trans. Royal Soc. of Edin.*, Vol. 41, part 2, No. 12.
[2] *Trans. Phys. Soc.*, Vol. 32, No. 2, p. 147.
[3] *Brit. Med. Journal*, April 17, 1897, p. 959.

Similarly I have seen fatal collapse on the part of an old woman who, having just had an eye removed under chloroform, was suddenly raised to the sitting position for application of a bandage.

The lowering of blood pressure by chloroform inhalation was well demonstrated in the human subject by Dudley Buxton.[1] He used definite percentages of chloroform and showed that with a 1 per cent. vapour the pressure sank at first slowly, then more quickly, from 130 mm. Hg. to 110. With 1·5 per cent. vapour it fell to 90 mm. in ten minutes. When the percentage was lowered again to 1 per cent. the pressure rose to 105 mm. in six minutes, where it stayed for the next twenty-five minutes, the inhaler having been removed and consciousness allowed to return. The Hyderabad Commission found that blood pressure was lowered by chloroform inhalation, but attributed this entirely to narcosis of the vasomotor centre. The Glasgow Committee, on the other hand, which agreed that the lowering occurred, held a direct effect of the drug upon the heart to be at least partly responsible.

The heart under the influence of chloroform has been subjected to experiment, observation, and controversy since the drug was first used. Snow stated that, " although the respiration may be suspended by an amount of chloroform which has very little effect on the action of the heart, it is quite possible to stop the heart's action by the immediate effect of this agent." He was perfectly clear about the effect of strong vapour of chloroform. " When animals of warm blood are made to breathe air containing as much as 8 or 10 per cent. of the vapour of chloroform the blood which is passing through the lungs becomes so charged with it as to stop the action of the heart. . . ." He further writes that " it is in this way that accidents from chloroform have happened." It is here, in the interpretation of clinical fatalities, that so much difference of opinion has been expressed. That some accidents arise in the manner described by Snow is as certain as it is that all do not. There is good evidence, both clinical and experimental, that the heart may stop under chloroform when no high percentage vapour has been inhaled. A great deal of experimental work has been done in order to determine how the heart's action is stopped by chloroform, and whether it is ever stopped before the respiration. The evidence of the Committee of the Royal Medical and Chirurgical Society, and later that of the Glasgow Committee, supported Snow's view that strong vapour of chloroform acted directly upon the heart, paralysing its action. These bodies further maintained that moderate doses weakened the action of the heart before death ensued, although respiration generally

[1] *Brit. Med. Journal*, July 14, 1906, p. 84.

ceased before the heart's action completely failed. The Glasgow Committee found that chloroform sometimes exerted "an unexpected and capricious action on the heart, causing a rapid fall of blood pressure." The Hyderabad Commission, seeking support for the clinical school which maintained that there was no danger from chloroform except through the respiration, declared that the drug had no direct action upon the heart. This opinion has been opposed by much subsequent experiment. Gaskell and Shore [1] subjected the Hyderabad evidence to destructive criticism, and further proved that chloroform exerted a direct paralysing influence on the heart and blood vessels. Leonard Hill further destroyed the evidence of the Hyderabad Commission by showing that faulty methods had been employed for registering the efficiency of cardiac contraction. Furthermore, this physiologist confirmed previous observations made by MacWilliam showing that chloroform produces a paralytic dilatation of the heart. The later work of Sherrington and of Embley has clearly proved that chloroform acts upon the muscle of the heart. The former, in conjunction with Sowerby, showed that the heart is affected by a lower concentration of chloroform than are the blood vessels of the limbs or the skeletal muscles. The experiments of Goodman Levy [2] show that light chloroform narcosis puts the heart muscle into a state of irritability during which it may easily be thrown into irregular contractions by a variety of stimuli. This ventricular fibrillation has been observed also by MacWilliam, who several years before had shown that dilatation of the heart's cavities took place under chloroform.

MacWilliam showed, what Levy has confirmed, the danger of intermittency in the administration of chloroform. In the laboratory, at any rate, fibrillation of the heart's muscle does not occur in continuous administration ; it often arises if the administration is interrupted and then restarted during a period of light narcosis. Levy shows how any stimulus—and the readministration of chloroform is one—may in these circumstances start irregular contractions of the ventricle.[3]

The practical importance of Levy's views, which we shall consider more fully when discussing fatalities, lies in their power to explain clinical accidents which are not to be accounted for on the grounds of overdosage with chloroform.

Apart from direct action upon the heart muscle, chloroform might affect the action of the organ by influencing the nerves which reach the cardio-inhibitory centre, or that centre itself.

[1] *Brit. Med. Journal*, Jan. 8, 1893.
[2] "Heart," 1913, Vol. 4, p. 319.
[3] *Brit. Med. Journal*, 1914, part 2, p. 499.

Much experimental work has been done to prove that such influence does actually come into play. Inhibitory effects upon the heart have been produced by stimulating the sensory nerve ends in nasal and laryngeal mucous membranes, and it has been maintained that the danger of using a strong chloroform vapour early in the administration is due to the possibility of such a reflex cardiac inhibition. Embley's researches [1] proved that a condition of heightened vagus susceptibility accompanied chloroform narcosis. Inhibition, however, he did not attribute to the action of the drug upon sensory nerve endings, but rather upon the vagus centre itself. Embley showed that cardio-inhibitory effects were easily produced when a vapour of more than 2 per cent. was inhaled, and the inhibition was intensified with high percentages. Such inhibition did not occur in animals in which the vagi had been divided, and intravenous injection of atropine before the inhalation had the same protective effect. Other observers have questioned this protective action of atropine. The physiological evidence hitherto accumulated concerning chloroform and the heart appears to prove that—

(1) The heart is subject to sudden arrest under the influence of chloroform.

(2) This may take place early in the administration, even when the vapour inhaled is not a strong one (under 2 per cent.).

(3) Strong vapours of chloroform easily stop the heart, whether early or late in the administration.

(4) Chloroform has a direct weakening action on the heart muscle. It also increases the susceptibility to vagus inhibition. This comes about through diminution of vagus control permitting irregular contractions, which may proceed to definite fibrillation of the ventricle, not through reflex inhibition of the heart's action. It is doubtful if permanent arrest ever occurs simply through reflex inhibition. With normal or increased vagus tone the tendency to irregularity of contraction is checked and that to fibrillation prevented (MacWilliam). The occurrence of heart failure is more likely when administration is intermittent than when it is continuous.

(5) When heart failure is gradually brought about by chloroform, breathing stops before the heart-beat.

The effect of chloroform upon *muscle* has been studied experimentally by Sherrington.[2] His work carried out with Sowton shows that heart muscle is more susceptible than skeletal muscle or the muscular coats of arteries and intestine to the depressant

[1] *Brit. Med. Journal*, April, 1902.

[2] "Report of Special Chloroform Committee B.M.A.," pp. 127 *et seq.*

effect of chloroform. In both tissues there is at first a slight constriction, and when the dosage of the drug is very low this constriction may be the only effect noticed. With stronger doses it is followed by a lasting relaxation. This relaxation was enhanced if carbon dioxide was present with chloroform in the circulating fluid instead of oxygen. The depression of the contraction of skeletal muscle is detectable with weaker solutions than is dilatation of blood vessels—*i.e.*, skeletal muscle is more easily affected by chloroform than the coats of the arteries. It is of practical importance to note that Sherrington states that "the weakest of the chloroform solutions with which we have got distinct evidence of influence in either direction on the skeletal muscle or the blood vessels in the limb have been more concentrated than should ever occur in the practical administration of chloroform by inhalation for anæsthesia." He points out also that there is considerable difference of degree in the action of chloroform upon blood vessels of different organs. In this connection it may be noted that Embley and Martin found marked dilatation of the vessels of the bowel and of the kidney, and this was confirmed by the work of Schäfer and Scharlieb. These observers, however, found that elsewhere than the renal vessels the muscular elements of peripheral blood vessels were constricted by chloroform. In the small intestine relaxation of its length and decrease or disappearance of recurrent contractions were seen during perfusion with chloroform solutions. Clinically there is frequent opportunity for noticing the behaviour of intestines during chloroform narcosis. Movements are rarely seen. Enterospasm as a pathological process is occasionally witnessed, and similarly peristalsis may be seen above an obstruction. Generally, however, all intestinal movement is absent as a result of reflex sympathetic inhibition, not as a direct anæsthetic effect.[1] There is loss of tone in the intestinal muscle due to the anæsthetic. It must be remembered, however, that the condition of the intestines generally seen at operation is partly owing to the previous preparation of the patient. The intestinal tract is usually, at operation, empty, and therefore even without any anæsthetic peristaltic contractions would be absent. Occasionally the intestines are found lying in close, undistended coils, as in a rabbit's abdomen. More often there is slight general distension. At other times some coils are quite contracted, others a little distended. The condition of absent distension commonly seen with spinal analgesia is not usual with narcosis, and this supports the contention that the commonly found state under

[1] *Lancet*, 1920, I. H. T. Gray on "Influence of Nerve Impulses on Visceral Disorders."

general anæsthesia is due to the reflex effect of incising the abdomen. The reflex is prevented by spinal injection, which blocks the afferent impulse of the reflex arc. Narcosis has no such complete effect in preventing reflex sympathetic stimulation. Little effect is to be observed on other organs, such as the cervix uteri, largely composed of unstriped muscle fibre. In one patient the abdomen being opened under chloroform, the stomach exhibited irregular contraction, causing it to assume almost an hour-glass form. When narcosis was deepened this disappeared. The stomach was incised and examined within and nothing abnormal found. When it was closed again narcosis was lightened at the surgeon's request to see if irregular contraction would come on again with straining. The stomach contraction did not reappear. We may take it that probably the actual effect on muscular tissue itself of chloroform in the strengths commonly employed is very slight, except in the case of heart muscle; the many muscular phenomena witnessed during chloroform narcosis, from spasm to flaccidity, are to be attributed to the influence on nerves supplying or centres regulating the muscle rather than to that on the muscular tissue itself.

Effects on the Nervous Tissues.—Chloroform has a selective action on nerve tissue. This is shown, among other evidences, by the undue proportion in which it can be extracted from the nerve tissues after death in comparison with the amounts present in equal weights of other tissues. The effect of chloroform on nerves is to diminish both irritability and conductivity. If the action is long continued, or if chloroform is applied to nerves in high concentration, it kills the tissue. Hamilton Wright states that the neurons are affected, and that there is rarefaction of the cell-substance.[1] Chloroform is a nerve poison, and is seven times as strong as ether in this respect. Waller has shown by nerve-muscle preparation experiments that the electro-excitability of nerves is lost under the influence of chloroform seven times as easily as with ether. It is worthy of note that clinically, too, this represents roughly their respective potencies. Chloroform acts upon the nervous system as a whole in the manner described on p. 41, the most recently developed regions in the cortex of the brain succumbing to its action before the vital centres of the bulb are affected. Exact evidence of the course of effects in human beings is not available. Yet from subjective sensations and from observation of symptoms we are probably right in inferring that the action of inhaled chloroform follows in man the course determined by physiologists for animals. We witness conscious excitement followed by excitement that is unconscious, and

[1] *Journal of Physiology*, Vol. 36.

shown by purposive and semi-purposive movements, excitability of reflexes, succeeded by reflex insensibility, initial stimulation of circulation and breathing, replaced by quiet pulse and regular, automatic respiration. The central nervous system, in fact, appears to be affected in man as it is in animals, and we may safely assume that if in him chloroform is given in too high concentration it will, as in animals, eventually produce a toxic paralysis of the vital centres of circulation and respiration.

In connection with its action on the nervous system we must allude to the *reflex phenomena* seen under chloroform. These give, as is seen in the account of the stages of narcosis, useful criteria for gauging the effect produced. For some reflexes are abolished earlier than others. The order is not constant, however, in different persons; nor is the readiness with which reflex phenomena are evoked. Some patients react easily; others, even when only in light narcosis, remain motionless in spite of strong stimuli. Generally speaking, the more feeble and the more phlegmatic the individual the lighter is the degree of narcosis in which he will exhibit no reflex response to stimulation. The order in which the reflexes disappear is to some extent dependent upon local conditions. If a part of the body is through inflammation or disease more than usually sensitive, reflexes will be more easily aroused by stimulus applied there than elsewhere. Thus reflexes from this part will persist longer than usual. For instance, generally the coughing reflex goes before the corneal. Often, however, I have observed that if the patient has a peculiarly susceptible larynx, as from smoking or from laryngitis caused in some way, then reflex laryngeal spasms may be evoked after the cornea has ceased to reply to stimulation. Reflex from an over-sensitive part can be elicited by a lighter stimulus than that needed to produce the same effect on normal tissues. Somewhat in similar fashion the heightening of nervous excitability by a stimulus may recall a banished reflex. For instance, if the corneal reflex has been abolished by anæsthesia and then a skin incision is made, it often happens that just after the incision the cornea is found to be reflexly active again. Hewitt has drawn attention to this phenomenon in these words: "A strong stimulus may induce a state of excitability in a centre or centres so that a reflex phenomenon, which was previously impossible, by reason of such centre or centres being inexcitable, now appears. This state of things is often met with in the spurious chloroform sleep of children."

The superficial reflexes are abolished before the deep. Conjunctival and skin reflexes have generally gone as soon as anæsthesia is reached (third stage of narcosis). Even this

statement has to be qualified, however, for the appearance or non-appearance of reflex movement will still depend partly on the violence of the stimulus. Thus if mere touching is the stimulus the skin reflex is always gone before the conjunctival. A cut of the skin, however, will often still evoke a reflex at a time when the conjunctival reflex has gone, so far as we can judge by touch, which is here the only suitable stimulus with which to test the sensibility. The corneal reflex is not abolished until the third stage has lasted at least a few minutes. The reflexes evoked by stretching the sphincter ani, by distending the bladder, by dragging on the uterus, may persist long after this, and in some subjects cannot be entirely abolished unless narcosis is pushed to the verge of bulbar paralysis. Always in considering this matter we must bear in mind the effects of disease. Reflex response, as elicited in the laboratory from a normal animal, does not teach us what to expect when the experiment is made upon a human individual suffering from some disability. Thus, for instance, the reflex excitability of a tubercular bladder, the straining occasioned by its distension, and the extreme difficulty of abolishing this reflex response by anæsthetics are phenomena quite beyond those displayed under ordinary experimental conditions for testing the bladder reflex. Again, in practice we become aware, particularly in connection with abdominal operations, of the difficulty with which anæsthesia overcomes protective reflex contraction that has been kept up over long periods of time. In some of these instances it is even probable that actual structural change in the muscle fibres has succeeded the long-continued contraction, rendering complete relaxation by anæsthetics a physical impossibility.

The occurrence of *changes in respiratory movements* as a reflex result of stimulation is common during operations. Broadly speaking, the lighter the narcosis the more apt are these changes to be witnessed. They are frequent during chloroform anæsthesia. Early in induction coughing is easily excited, especially if too strong a vapour is offered for inhalation. At this time there are frequently swallowing movements, probably excited by saliva that is excreted with more than normal freedom. Reflex holding of the breath may occur. At the first incision, if there is any reflex alteration of the breathing, this generally quickens and deepens. It may, however, be inhibited. Neither of these alterations persists, nor are they dangerous. The reflex brought out by stretching the anal sphincter commonly takes the form of a spasmodic, long-drawn, high-pitched inspiratory noise, often spoken of as the *rectal cry*, and a similar reflex sometimes accompanies pulling down of the cervix uteri or forcible stretching of the vagina.

Intra-abdominal manipulations cause reflex grunting sounds accompanied by contraction of the muscles of the abdominal wall. When the peritoneum is first picked up or incised there is commonly a reflex depression or stoppage of the breathing, just as is occasionally seen at the moment of the skin incision. And the same symptom is quite usual when a hernial sac is dragged upon or if Douglas's pouch is forcibly invaded, as during a hysterectomy or other pelvic operation. Similar respiratory depression may accompany the delivery of a kidney on to the loins. Reflex effects upon the breathing are commonly evoked, too, in operations involving deep structures of the neck, as, for example, some removals of goitre and of deeply placed cervical glands. When the pleura is incised under chloroform a reflex cough is usually set up; in fact, the narcosis is generally kept light in order to allow of the appearance of this symptom, which is beneficial as helping to expel the contents of an empyema. Generally speaking, the stimulus supplied by surgery increases rather than diminishes respiratory activity, and the breathing is usually seen to become less vigorous and is heard to be quieter when an operation is finished than while it is in progress.

During early periods of chloroform anæsthesia the *pupil* may be subject to reflex variation. Thus it is not uncommon to see the pupil dilate immediately after the skin incision. For this reason, and because other surgical procedures also may affect the pupil, it is unwise to take its size as a gauge of the depth of narcosis, during the early stages, at any rate, of an operation under chloroform. When after these variations the pupil settles to its normal size for chloroform anæsthesia (2 to 3 mm. in diameter), the anæsthetic having been inhaled for a quarter of an hour or so, then it becomes a reliable guide taken in conjunction with an absent corneal reflex. A dilating pupil shows deepening of the narcosis, and a contracting the lightening of it. A dilated pupil that does not react to light shows very deep narcosis. Nevertheless there is this obstacle to relying solely on the pupil—that just before vomiting the pupil is commonly widely dilated and may not react to light, and the cornea may remain insensitive. Therefore, even when the pupil has settled down it must not be regarded as an infallible indicator of depth of narcosis, although after this its gradual increase or decrease does most often denote increased or diminished narcosis (see p. 46). The influence that carbon dioxide exerts upon the pupil must be borne in mind. The cyanosed patient will show a contracted pupil even during a degree of narcosis which would, in the properly oxygenated subject, be accompanied by a dilated pupil; and the

influence of cyanosis on the pupil may outweigh the reflex result of stimulation. The same remark applies to sufficient doses of morphia.

Reflex *circulatory* phenomena are also common during chloroform narcosis. In the first stage, before consciousness has gone, the psychic stimulus of fear may be shown by quick, feeble pulse, pallor of the face, and a wide pupil. It must be remembered that in pre-anæsthetic days deaths undoubtedly occurred not only from fright before operation, but at the moment of incision. Therefore, if operation is allowed to start before consciousness is completely abolished and anæsthesia properly instituted, we may reasonably expect untoward symptoms to follow on a stimulus inflicted upon a brain not yet fully protected. At the same time the fact that such reflex effects when fatal have been confined to chloroform must make us chary of regarding them purely as psychic or reflex results independent of the action of the anæsthetic drug employed. If this were so, like fatalities should have attended some of the innumerable instances in which operations have begun on patients imperfectly anæsthetized with ether or with nitrous oxide. Reflex inhibition of the heart by vagal action, consequent on stimulation of the sensory nerve-ends in the air passages, is held by some physiologists to explain early circulatory depression in chloroform anæsthesia.[1] This explanation has been offered for fatalities occurring early in chloroform narcosis, and French physiologists, including Dastre, have laid stress on the "*syncope-laryngo-réflexe*." Embley demonstrated the occurrence of vagal inhibition during chloroform inhalation, particularly if the inhaled vapour were over 2 per cent. He was not satisfied, however, that the cause of the inhibition was excitation of sensory nerve-endings.

Levy [2] attributes the circulatory phenomena of rapid, feeble pulse or inhibited heart early in chloroform anæsthesia to irregular ventricular tachycardia or actual fibrillation, and states that these phenomena may be caused by "accelerator impulses originating as a reflex from the excitation of sensory nerves. Experimentally irregularities (of ventricular beat) are readily induced by comparatively mild forms of sensory excitation, such as cutting the skin. . . ." Changes in the blood pressure early in chloroform narcosis are attributed by Wood and Hume [3] to reflex inhibition of heart and vasomotor centre, causing a fall, followed by a rise in pressure due to reflex vasomotor spasm.

[1] *Journal of Physiology*, Vol. 36.
[2] *Proc. Royal Soc. Med.*, Vol. 7, No. 8, Section Anæsthetics.
[3] *Medical News*, Feb. 22, 1890.

The reflex circulatory effects seen during chloroform anæsthesia are sometimes a rise, sometimes a fall, in blood pressure, sometimes a hastening, sometimes a slowing, of the pulse. Mechanical stimulation of sensory nerves has been shown experimentally to produce at first pressor and later depressor effects. Clinically we see generally the same rule hold. The various forms of stimulation to which we have alluded in connection with breathing produce under chloroform more often transient rises in blood pressure and increase in pulse rate than the opposite. The importance of reflex circulatory effects depends upon the depth of the chloroform narcosis. When this is extreme the blood pressure is already so lowered that any additional depression from a reflex cause becomes of grave moment. Normal chloroform anæsthesia is accompanied by some stimulation of the vasomotor centre, and depressor results of reflex stimulation do not produce a serious condition of the circulation. For instance, certain surgical proceedings, such as the division of the spermatic cord during the operation of castration, the cutting of the optic nerve before enucleating the eyeball, and others, were long looked upon as especially liable to be accompanied by acute circulatory depression. Actually if the anæsthesia is at a proper level these effects are rarely witnessed. A transient, slight circulatory depression is all that follows on the traumatic stimulus if there is any depressing effect to be appreciated at all. These circulatory changes are certainly more often seen during chloroform anæsthesia than during that due to ether, yet even with chloroform, unless the narcosis is too profound, they are generally brief and without danger. The reflex circulatory effect of traumatic stimulus may, however, be profound when that stimulus is violent or long continued. The circulatory effect is then merged in that general state of depression which we call shock and which is treated elsewhere (p. 322). Here we may only note that shock is more easily produced during chloroform anæsthesia than during that due to ether or nitrous oxide.

Effect of Chloroform on Glands

Chloroform stimulates the secretion of mucus and saliva in the early periods of narcosis. The flow of these materials is, however, not nearly so profuse as that caused by ether. The sweat glands appear to be still less affected, although during shock under chloroform there may be a noticeable perspiration. The secretion of the lachrymal gland [1] has been carefully observed

[1] *Lancet*, May 10, 1919, p. 792.

clinically by the late L. T. Rutherford. He states that under chloroform the quantity of the lachrymal secretion is small, but is at once evident. The lachrymal glands become active with the onset of the second stage of narcosis, pools of secretion appearing at the inner canthi. During surgical anæsthesia the glands cease to secrete, and the canthi, if dried after the second stage, remain dry. The cessation of the secretion usually takes place a few breaths before complete abolition of the corneal reflex, although the two may cease together. The gland never continues to secrete after abolition of the corneal reflex. Rutherford deduced the rule that the moment at which lachrymal secretion is first observed after its cessation under the influence of chloroform provides a reliable indication of the moment at which to continue administration if satisfactory surgical anæsthesia is to be prolonged. He also held that the secretion afforded a valuable means of distinguishing between the dilated pupil of overdose and that of impending vomit.

The effects which chloroform may produce upon the *liver* are known from examining animals killed after experiment and from *post-mortem* examination of human subjects who have succumbed after post-anæsthetic toxæmia. There is no other evidence that I can discover of changes due to chloroform observed in the liver of human beings who have died shortly after or during anæsthesia. Fatty degeneration of the liver has been found in dogs some hours after a single long inhalation. The same change has been produced in animals by giving them short inhalations of chloroform repeated many days running. These fatty changes have been held to result from the action of chloroform in destroying red blood corpuscles and also from its action on the tissue cells of the liver. Sir Humphrey Rolleston informs me that chloroform may alter the functioning of the liver cells, and that when jaundice is due to chloroform this altered functioning is the prime cause. The hæmolysis would not be enough to produce jaundice unless there were also inflammation of the hepatic cells. Similarly Brulé [1] states that chloroform inhalation may cause passage of urobilin and biliary salts into the urine. A long inhalation may cause jaundice, which is a urobilinuric jaundice of hepatic origin and nothing to do with hæmolysis. The retention of urobilin is the cause of the jaundice and is due to improper working of the liver cells. The original observations of Ungar, Junker, Strassmann and Ostertag [2] on the fatty degeneration caused in the livers of animals by chloroform have been confirmed by later observers. G. H. Clark found that with rabbits very small

[1] " Recherches Récentes sur les Ictères," 1919, p. 137.
[2] Hewitt's " Anæsthetics," 4th ed., p. 85.

doses given daily were more dangerous than one large dose, and Offergeld showed that animals which had been chloroformed for long periods of time might recover well from the immediate effects of the anæsthetic, but die in from forty-eight to sixty hours, showing *post-mortem* parenchymatous degeneration of the liver, as well as of the heart and kidneys. The fatty liver is the most constant *post-mortem* feature of post-anæsthetic toxæmia in man. It is further discussed with that condition (p. 214).

On the *kidneys* chloroform appears to have a paralysing influence. Secretion is diminished soon after the beginning of the inhalation and is almost completely arrested during deep narcosis. That it is not quite stopped in human subjects we know from the use of the cystoscope, which has enabled surgeons to watch the escape of urine from the ureters into the bladder. Usually the patient has had very little fluid for some hours before operation, and therefore, apart from any effect of the anæsthetic, secretion is not likely to be brisk during anæsthesia. The fatty degeneration which we have seen affect the liver of animals after repeated administrations of chloroform has likewise been found, though to less extent, in the kidneys. Indeed, the postponed deaths after chloroform to which we have alluded above were attributed by Offergeld to the effect of the drug upon the cells of the kidney. Hogan [1] points out that kidney secretion is diminished during anæsthesia, not because of a specific poisonous effect of the anæsthetic on the kidneys, but because of its effect on the tissues and organs of the body generally. These are subjected during anæsthesia to a lack of oxygen, their acid content is thus raised, and this makes them absorb more water from the blood. Since it is only free water brought to the kidneys by the blood that is excreted as urine, this is necessarily diminished during anæsthesia. If the acid intoxication accompanying anæsthesia is severe, albumen and casts appear in the urine. According to some observers, temporary albuminuria is common after chloroform inhalation, and pre-existing albuminuria is increased. Others have found traces of chloroform in the urine as long as twelve days after inhalation. Vitali [2] found that chloroform does not pass into the urine. Hogan, examining 400 post-operative urines, found that 49 per cent. showed acetone or acetone and diacetic acid. Twenty-six per cent. showed albumen and casts. Whenever this was noted there was also found a low chloride output.

[1] *American Year Book of Anæsthesia*, 1915, p. 172.
[2] Gwathmey's "Anæsthesia," 1914, p. 309.

The other glandular tissues of the body are, so far as we know, unaffected by the action of chloroform in usual doses. Delbet,[1] however, believes that the drug has especial affinity for the suprarenals and checks their function.

[1] Gwathmey's "Anæsthesia," 1914, p. 304.

CHAPTER VI

PHYSIOLOGICAL ACTION OF ETHER

"The physiological effects of ether are essentially the same as those of chloroform," Snow wrote, and, indeed, the description of narcotic effects in stages which we have given in connection with chloroform (p. 45) was originally applied by him to the action of ether. Like chloroform, ether is a stimulant in the early stage of its action and a narcotic only after that. It is a powerful stimulant to the circulation, breathing, and most glandular structures, the stimulating effect continuing until the toxæmia of overdosage. As to its **action on the nervous system** generally, we may apply the descriptions given of chloroform. There are the same initial excitement of ideas, tingling sensations and feelings of warmth in the limbs, the same rambling speech, semi-articulated sounds, muscular excitement, and subsequent relaxation. The effect of prolonged ether inhalation upon the nerve-cell has been studied by G. Butler.[1] Anatomical changes in Purkinje's cells of dogs are described. The changes are at first those of mild activity, and later there are superimposed changes of depression, depending for severity upon the duration of the anæsthesia. These changes first make their appearance after about two hours' narcosis. After six hours the depression is still moderate; after eight it is marked. Later profound depression is present with the beginning of necrobiosis. The changes in the cells vary in degree in animals of the same species kept under the same form of anæsthesia for the same length of time. An anæsthesia of several hours' duration on several successive days produces the same degree of depression in the nerve-cells as a continuous anæsthesia of the same number of hours. Animals easily kept under show more marked anatomical changes than those kept under with difficulty. The collapse which occurs after eight hours or more of anæsthesia is regarded as the last constitutional effect of a diffusely acting depressant. The cells in depression contain increased amounts of chromatin and nucleolar substance, while the plasma is deficient in chromatin. There is little or no basic staining substance left. At complete depression the nucleus appears as a homogeneous mass taking

[1] *Journal of Med. Research,* Vol. 34, 1916, p. 325.

the basic stain predominantly, as opposed to the more granular acid-staining appearance of the cytoplasm. Finally there is disorganization of the nucleus, which fuses with the cytoplasmic mass. Forbes and Miller [1] sought to localize the action of ether. They experimented to determine by means of action currents whether ordinary surgical anæsthesia blocks afferent impulses, resulting from peripheral stimulation, at the synapses through which they pass on their way to the cerebral cortex. It was necessary first to ascertain whether in nerve trunks profound narcosis abolishes the action currents which are an index of nerve impulse. It was found that, even with administration of ether pushed to the point of abolishing respiration, action currents could be led off from a motor nerve under direct stimulation. Peripheral afferent neurones extend centrally as far as the medulla. In view of the results obtained with nerve-trunk experiments, we should expect no interruption of action currents by ether before this point. The effect of ether must be centred in neurones central to the medulla. Experiments were carried out with one electrode placed on the posterior corpora quadrigemina on one side and the other at the base of the brain-stem 2 or 3 mm. on the opposite side of the median plane. Stimulus was then applied to the sciatic on the same side as the upper electrode. With this arrangement it was found that surgical anæsthesia with ether greatly reduced or altogether abolished the excursions of the galvanometer. This effect occurred long before the respiration was interfered with. The authors conclude that, "since ether abolishes or greatly reduces the magnitude of impulses in those neurones which arise in the medulla, it is more than likely that any impulse persisting in this region will be abolished in the next set of synapses in the chain leading to the cortex." Surgical anæsthesia, in fact, appears to protect the cerebral cortex from incoming nerve impulses. One striking and important difference there is, however, between the physiological actions of ether and chloroform. Ether has **no paralytic action on the heart** comparable to that which we have found that chloroform can exert. If death is brought about by ether it occurs through the toxic action of the drug paralysing the respiratory centre. Neither experimentally nor clinically do we see deaths due to ether comparable to those which are brought about early in chloroform narcosis.

The *strength of ether vapour* necessary to induce anæsthesia is much greater than that of chloroform. Snow stated that a patient requires "to inhale about 30 per cent. of vapour of ether in order to be rendered insensible in a convenient time." This

[1] *American Journal of Phys.*, 1916, Vol. 40, p. 148.

overstates the case, according to more recent investigations. Indeed, Waller found that from the commonly used open mask it is difficult to obtain a percentage as high as 20 per cent. Hewitt and Symes found that with a flannel mask and excessive quantities of ether they could not raise the percentage above 12.[1] These observers tested the effect of using different materials for the cover of the mask.[2] They found that the ether percentage provided varied between 5 and 15, according to the extent to which the liquid was poured on the mask and according to the nature of the fabric employed. Gauze yielded a higher percentage than flannel, the vapour provided becoming stronger the more layers of gauze used. With one layer of flannel or of lint on the mask, placed on a face-pad and surrounded with a collar, so that adventitious air could not enter at the mask rim, a fairly constant vapour of 8 or 9 per cent. could be depended on. These results were obtained by drawing air and ether vapour through the mask by means of a pump. Inspiration is thus imitated, but there is no corresponding imitation of expiration. The moisture condensed from expired air is not reckoned with, and this might alter the results considerably in the case of lint, which in actual practice becomes sodden, so that ether ceases to vaporize from it properly.[3] Stuart Ross [4] has made observations upon the amounts of ether vaporized by sending air through or over the liquid, as is done in the vapour-supplying apparatus of Junker, Shipway, and others. The percentage is increased by pumping air through instead of over ether. The figures were :—

Water Bath at 75° F.

Quantity of Ether.	Rate of Pump.
100 c.c.	30 per minute
Air blown over surface of ether gave percentage of ether	12·8
Air bubbled through ether gave percentage of ether	23·8

With ether in a glass bottle standing in a water bath and with its roof pierced by two tubes, one coming from the pump and the other going to a Waller's tube for weighing, Stuart Ross obtained the results shown in table on p. 75, blowing over the surface of ether. The air was propelled for five minutes, by which time the cooling effect of the ether was very marked. Some of the conclusions drawn by this observer were that the effect of a water bath is powerful in increasing the strength of the vapour yielded, that the more forcible the blast of air blown over or through ether the less is

[1] *Proceedings of the British Association* (Anæsthetics Committee), 1911.
[2] *Lancet*, Jan. 27, 1912, p. 215.
[3] "Anæsthetics," J. Stuart Ross, p. 205.
[4] *Ibid.*, pp. 201, 202.

Temperature of Bath before Experiment.	Quantity of Ether before Experiment.	Rate of Pump (per Minute).	Temperature of Ether at End of Experiment	Percentage obtained.
75°	100 c.c.	30	50° F.	12·7
85°	100 c.c.	30	52° F.	12·8
85°	100 c.c.	90	45° F.	8·8
No water in bath.	100 c.c.	90	23° F.	5·4

the percentage of ether yielded. This loss of percentage is not compensated for by the increase in the total amount vaporized. These results apply only to a strong current of air. If the current of air were very small, a little increase in the air stream would increase the total amount of ether vaporized without reducing the percentage strength. Regarding the quantity of ether that must be absorbed to produce anæsthesia, Snow calculated from his experiments that for the third degree (surgical anæsthesia) rather over 4 drachms were in the system. The second degree was reached with rather over 2½ drachms, and the fourth with nearly 6.

Connell [1] has estimated the percentages of ether needed to induce and maintain anæsthesia with ether. His figures are :—

Period of Anæsthesia.	Percentage of Ether.
First five minutes (include induction) .	18
Next twenty-five minutes	14
Next thirty minutes	12
Next sixty minutes	12·8

Difficult subjects required on an average an extra 4 per cent. during the first half-hour, feeble patients 2 per cent. less than the above. Using an apparatus designed for routine administration of ether in measured doses, A. H. Miller [2] found that 15 to 30 per cent. by weight of ether vapour was required for anæsthesia. His apparatus consisted of a cone with a gauze chamber so arranged that a space of 4 inches existed between the face and the chamber when the cone was firmly applied. The ether was supplied from a syringe holding 1 ounce. Karl Grahe [3] claims to have shown that a portion of the ether inhaled undergoes oxidation and remains behind in the organism.

Ether stimulates the *respiration*. After the initial rapidity of the induction stage is over and automatic breathing has set in this goes on at a more rapid rate than in the conscious organism. Clinically

[1] *Journal Amer. Med. Assoc.*, March 22, 1913.
[2] *International Clinics*, Vol. 4, 24th series, p. 250.
[3] *Zeitschrift Allgemein. Physiol.*, 1911, Vol. 13, pp. 111—134.

the rate and character of the breathing vary enormously, as we shall see in accordance with the method employed to give ether; the more air-deprivation, the more vigorous, as a rule, are the respiratory movements. Before anæsthesia is reached the breathing is interrupted by swallowing movements and by spasm both of the muscles of the fauces, tongue and jaw, and of the muscles of respiration. Although ether vapour is much less pungent than that of chloroform of equal percentage, yet, as it has to be used in much greater concentration, it is in practice irritating to the air passages. Thus, during induction there may be coughing or holding of the breath if the vapour is allowed to be too strong, and this irritating quality of the vapour is enhanced by the coldness caused by the evaporation of the ether. If warmed the vapour is more easily inhaled. Coughing and swallowing early in narcosis are also caused by irritation of the pharynx or larynx by mucus, the secretion of which is stimulated by ether inhalation. When ether is infused or given *per rectum* there is less of the coughing and swallowing, which shows that the secretion of mucus is partly due to local influence of ether vapour. The stimulating effect of ether upon the breathing continues to be exerted throughout its inhalation, unless this is pushed to the point at which paralytic toxic effects on the medulla begin. Then the respiration becomes irregular, infrequent, and, if the drug is still inhaled, finally ceases. The action of ether on the muscles of the glottis was studied by Victor Horsley and Semon, who showed that in light narcosis ether caused adduction, but in deep narcosis abduction, of the vocal cords. The importance of this in practice is shown on p. 264 (footnote 2).

The **action of ether on the blood** has not received so much attention as that of chloroform. Some observers describe hæmoglobin destruction; others find none. It seems clear that the drug has little destructive action on the corpuscles of the blood, and that it interferes with the carrying of oxygen to a far less extent than we saw was true of chloroform. Hamilton Fish [1] affirmed that ether reduces hæmoglobin and affects the red corpuscles. So, too, Boston and Anders,[2] both in the human subject and in rabbits, found reduction of hæmoglobin content, the lowest point being reached from twenty-four hours to thirty-six after anæsthesia. They found changes in the red cells always present as the result of ether anæsthesia, the central biconcavity being obliterated, or streaks and patches of pallor being disseminated over the surface of the cells. Da Costa and Kalteyer found hæmoglobin reduction of 3 per cent. in fifty cases of ether anæs-

[1] *American Year Book of Anæsthesia*, p. 35.
[2] *Ibid.*, p. 36.

thesia. Chevrier [1] states that *cholæmia* is a constant phenomenon after ether anæsthesia. It never reaches the point of causing jaundice, but is always found if the blood is examined cholemimetrically during the two days following inhalation. The cholæmia is highest on the first or sometimes on the second day after administration, and lasts five to eight days. According to Casto,[2] coagulation processes in the blood are hastened by ether anæsthesia, and the effect is produced wholly through the action of ether on the adrenals. This authority states that the acidity of the blood (H-ion concentration) may be increased by ether, the restoration of the normal reaction of the blood being complete forty-five minutes after the administration of the anæsthetic ceases.

The effect of ether in diminishing the *catalase* content of the blood has been studied by W. E. Burge,[3] who shows experimentally that the decrease in the amount of this substance evident in the blood of animals during ether anæsthesia is due to destruction of the catalase, not to inhibition of its activity. Evidence shows that catalase is formed in the liver and given off to the blood during exercise, combat, the excitement stage of narcosis, and on similar occasions. It is carried to the muscles and used in the increased oxidation of muscular activity, which it presumably renders possible. Blood catalase is destroyed *in vitreo* by exposure to ether vapour, and is not restored by the bubbling through of oxygen. Increase or decrease of oxidation in the organism appears to be accompanied by corresponding increase and decrease in the catalase of muscle. The decreased oxidation of anæsthesia is accordingly accompanied by a decrease in catalase, presumably after an increase when there has been a marked excitement stage.

The *amino-acid content* of blood serum during ether anæsthesia has been estimated.[4] It was found to be not materially decreased by fifteen minutes' ether anæsthesia in animals—

(1) After a week of meat diet ;
(2) After a week of diet low in protein ;
(3) Half an hour after a meat feed ;
(4) Half an hour after a carbohydrate feed.

The content was decreased to 4·6 from 9·2 per cent. after an amino-acid rise due to four hours of meat digestion.

Glycosuria [5] associated with *hyperglycæmia* has been shown experimentally to be caused by ether. The glycosuria depends on the quantity of ether used and the duration of time during

[1] *Soc. de Biologie, C. et Memoires*, Vol. 32, 1919, p. 401.
[2] *American Year Book of Anæsthesia*, 1915, p. 43.
[3] *American Journal of Phys.*, 1917, Vol. 44, p. 290.
[4] *Journal of Biol. Chem.*, Baltimore, 1916, Vol. 27, p. 45.
[5] *American Journal of Phys.*, Vol. 48, 1919, p. 146.

which it is given. It occurred regularly in animals fed on meat, in animals fed on carbohydrates only if the anæsthetic was given within ten hours of the last meal. The intravenous administration of oxygen prevented the appearance of glycosuria. Even slight degrees of asphyxia affected the level of the glycæmia. The authors concluded from their experiments that a persistent hyperglycæmia occurs in normal dogs under continuous ether insufflation. It reaches its maximum at the end of two hours. If the splanchnic nerves were cut a transient hyperglycæmia occurred, passing off at the end of two hours. Denervation of the hepatic artery caused a rise in glycæmia equal to that in normal dogs. The glycæmia is attributed to an active participation on the part of the liver capillaries and cells.

The effect of ether on the *vascular system* as a whole and on the *blood pressure* appears to be slight, since different observers have interpreted it in opposite directions. Thus Kemp found that ether caused a general rise of arterial pressure, while MacWilliam stated that the vasomotor centre was depressed, with consequent arterial dilatation and general, but slight, fall of pressure.[1] W. E. Munns' more recent work to some extent explains these divergent results, for he showed that blood pressure sometimes falls and sometimes does not during prolonged inhalations of ether.[2] In these experiments dogs were given ether for hours by an intratracheal tube, one leg being enclosed in a plethysmograph. At the end of the first hour all the dogs showed vasodilatation, the normal tone and resistance of the arteries being destroyed. In half of the dogs experimented with a decided and eventually fatal fall of blood pressure ensued ; in the other half the tension was maintained. Munns ascribed the difference to the behaviour of the heart in the two sets of animals. If the heart fails to compensate and to increase the ventricular output, either because of inherent disease or weakness or because of too early response of the nerve centres to the effect of the anæsthetic, then the blood pressure falls. Mann [3] has shown that the blood pressure varies with the tension of ether in the organism. In dogs surgical anæsthesia is present when the tension ranges between 36 and 48. At tensions above 48 the animal becomes profoundly narcotized, respiration fails, and blood pressure falls to a low level. The corneal reflex usually goes at any tension above 40. At tensions lower than 36 to 45 the blood pressure is not depressed, or only slightly, and quickly recovers even after many hours of inhalation. After an hour or two of a tension of

[1] Hewitt's " Anæsthetics," 1912, pp. 94, 95.
[2] *Amer. Journal Surgery*, Anæsthetics Supplement, Vol. 31, No. 10, p. 113.
[3] *Ibid.*

45 to 55 the pressure is greatly depressed, and only partially recovers on withdrawal of the ether. Clinically the fall of blood pressure after long inhalations of ether is familiar, but then it is complicated by the trauma of long operation, which in itself can bring about the fall through the exhaustion due to protracted stimulation. Mann, investigating *vascular reflexes*, showed that the pressor effects of stimulation are greatest when the ether tension is 36 to 45 ; at 50 they are barely perceptible, and do not occur at all at higher tensions. The *reflexes* generally under ether are less easily aroused than under chloroform. Thus reflex interference with breathing and with the circulation is less often seen during operation, and when occurring is of less import. The patellar reflex has been found to persist in animals during complete ether anæsthesia.[1]

The stimulating effect of ether is shown freely by the increased secretion of *salivary*, *sweat*, and *mucous glands*. The secretion of *urine* is also increased at first, but diminishes during full anæsthesia. Bone [2] found increase in the first fifteen minutes counting from the start of induction. Then the rate diminished rapidly, being lowest after forty-five minutes, when it rose again. The percentage of urea in the urine was diminished. The Trendelenburg position caused unusually great diminution in the secretion of urine, either from retention in the renal pelvis or from some arrest of secretion due to the position. Kemp believed that the diminished secretion of urine was due to contraction of the renal arterioles, which he found as a special effect of ether inhalation. Buxton and Levy, repeating his experiments, concluded that the effects Kemp described only followed excessive use of ether.[3] Pechell described a fall in urea excretion on the day following inhalation, succeeded by a rise on the two next days.[4] We have seen (p. 77) that there is some evidence suggesting that ether affects the function of the *liver* cells, but its power in this respect seems far inferior to that of chloroform. The effects upon the *lungs* which have been attributed to ether will be best considered under its clinical aspect.

The *temperature* of the body falls during the action upon it of ether. Warming the ether vapour lessens this effect. Too great warming may lead to hyperthæmia if the body is covered. There is evidence suggesting that the decrease in body temperature due to ether is strictly analogous with that occurring during natural sleep. In both conditions the decrease in males is more than

[1] Hewitt, *loc. cit.*, p. 97.
[2] *Amer. Journal Obstetrics and Gynæcol.*, June, 1909, p. 1004.
[3] Hewitt, *loc. cit.*, p. 97.
[4] *Brit. Med. Journal*, June 20, 1903, p. 1425.

double that in females.[1] On the other hand, Pembrey and Shipway [2] show that the analogy must not be too closely pressed. During sleep the muscles are in a condition of tone and are not paralysed, and there are responses to tactile and thermal stimuli, although the excitability of the nervous system is lowered, metabolism diminished, and the temperature decreased. There is evidence that the regulation of the production and loss of heat is imperfect. In anæsthesia there is paralysis. The paralysed muscles produce less carbon dioxide and less heat, the nervous system will not respond readily to external stimuli, the regulation of temperature is abolished and chemical changes in the cells of the body follow the ordinary law—that is, they rise and fall with temperature. The temperature has an important effect on respiration and circulation. Rise of temperature increases the excitability of the respiratory centre and quickens the heart beat. The paper quoted shows the discrepancies between rectal and mouth or surface temperature. Details are also given of the loss of temperature in animals subjected to ether and of the influence of normal ether in preventing loss of temperature during operation on human patients. The reader is recommended to peruse the article entire.[2]

[1] *Amer. Journal Surgery*, Anæsthetics Supplement, April, 1917, p. 48.
[2] *Guy's Hospital Reports*, Vol. 69, pp. 223 *et seq.*

CHAPTER VII

PHYSIOLOGICAL EFFECTS OF NITROUS OXIDE, ETHYL CHLORIDE, AND SOME LESS COMMONLY USED ANÆSTHETICS

Nitrous oxide produces on the **nervous system** effects similar to those brought about by chloroform and ether. It is, however, free from the toxic power of these, and is altogether a less powerful agent and is incapable of producing the same degree of muscular relaxation. Its power of protecting the cerebrum from centripetal stimuli is, however, greater than that of these anæsthetics according to Crile. This observer states [1] that during nitrous oxide anæsthesia the histologic changes caused in the brain, adrenals and liver by exertion are repaired, as they are in normal sleep. Crile found lesions of brain, adrenals, and liver caused by nitrous oxide anæsthesia identical with those brought about by the intravenous injection of acids and with those caused by insomnia, exertion, infection, or physical injury. He believes that nitrous oxide protects the brain against histologic changes due to infection, whereas ether increases the damaging effect. Crile found also that acidity of the blood was increased and its reserve alkalinity decreased by nitrous oxide.

Nitrous oxide has **specific anæsthetic action,** and does not produce its effects by mere asphyxia, as was at one time supposed. Teter has pointed out that if the anæsthesia were merely due to cellular asphyxia a gas such as pure nitrogen, if supplied along with oxygen, should give results as good as those due to nitrous oxide and oxygen. But if enough oxygen is combined with nitrogen to keep the patient pink no anæsthesia is obtained. This authority states that if an anoxæmic narcosis is conducted for any length of time by means of nitrous oxide, an asphyxial acidosis, due to suboxidation, occurs in many instances, but with patients kept pink during the anæsthesia no such acidosis is obtained. It is interesting to note in connection with the acidosis that may arise during anæsthesia from nitrous oxide that the earliest explanation of its action in producing narcosis was based on the assumption that the gas was decomposed in the blood and that the over-production of oxygen led to the formation of such quantities of carbonic acid that "internal asphyxia" resulted

[1] *American Journal Surgery*, Anæsthetics Supplement, 1917, Vol. 31, p. 42.

(Davy). Jackson found the motor areas more sensitive under nitrous oxide than under ether.[1]

Its presence in the *blood* appears to be unaccompanied by any disorganizing effect on the corpuscles. It is very soluble in blood, but there is no evidence to show in what way it is held there, whether in some sort of combination with the corpuscles or merely dissolved in the plasma. Buxton has shown the affinity of nitrous oxide for iron salts, which are present in hæmoglobin, and also its solubility in albuminous solutions such as the plasma. Casto [2] described hæmatological changes in the blood of rats under nitrous oxide. After thirty minutes to one hour of anæsthesia with nitrous oxide and oxygen the red cells were decreased in number; no poikilocytes or nucleated cells were present. The polynuclear neutrophytes decreased and the lymphocytes increased in number. The alkali reserve of the blood was depleted and the H-ion concentration was slightly greater than normal. The conclusions of Hamburger and Ewing from their experiments [3] on man and animals with nitrous oxide were—

(1) Hæmoglobin is not permanently reduced, nor is anæmia caused;
(2) Changes in the readings of hæmoglobin and erythrocytes are transient and most likely to be explained by capillary stasis. Reduction of hæmoglobin is due to accompanying asphyxia, not to the anæsthetic itself;
(3) Changes in coagulation time are not constant, but in general there is increase in the time required for clotting.

Buxton states that, watching the blood in the web of a frog's foot while the animal was in a bell-jar of nitrous oxide, he was able to observe that there was no breaking up of the corpuscles. Arterial blood shaken up with nitrous oxide *in vitreo* grows darker. Left free in contact with air, blood soon parts with its nitrous oxide. Further work showed the falsity of the idea that nitrous oxide is decomposed during its presence in the circulation, and the theory that narcosis due to the gas was attributable to hyper-oxygenation had to be abandoned.[4] Instead the anæsthesia was attributed to asphyxia, and this idea was supported by the obvious resemblance of the symptoms displayed by a patient when fully narcotized with nitrous oxide to those that occur during acute asphyxia. Duskiness of face, jerky, stertorous breathing, violent muscular contractions, and swelling of the tongue are produced by a simple non-respirable gas, nitrogen, just as they are

[1] *American Journal Surgery*, Anæsthetics Supplement, 1917, Vol. 31, p. 66.
[2] *Dental Cosmos*, 1915, Vol. 47, p. 881.
[3] *Journal Amer. Med. Assoc.*, 1907, Vol. 51, p. 1586.
[4] Hewitt's "Anæsthetics," 1912, p. 87.

by pure nitrous oxide (Sir G. Johnson). Neither gas is respirable beyond a certain point, after which fatal asphyxia is caused. In the case of nitrous oxide, however, if these anoxæmic symptoms are prevented by due supply of oxygen, anæsthesia is still obtainable. With nitrogen, if the asphyxia is prevented, anæsthesia is prevented also. Dennis Jackson [1] has shown that with dogs it is impossible to produce anæsthesia quickly with nitrous oxide and oxygen at atmospheric pressure, unless the oxygen content is so low that loss of consciousness is due almost entirely to lack of oxygen. If enough time is allowed for the gas to act and CO_2 to be removed anæsthesia results. To Paul Bert and to Andrews of Chicago we are indebted for much of the knowledge and practical application of the effects of administering air or oxygen with nitrous oxide. Bert, however, believed that positive pressure was essential for the production of anæsthesia by nitrous oxide and oxygen. Largely owing to the work of Hewitt, we know that this is not so, and that under ordinary atmospheric pressure narcosis is obtainable with as much as 20 per cent. of oxygen. Jolyet and Blanche [2] showed that nitrous oxide cannot support animal or vegetable life owing to lack of available oxygen. In man the average inhalation lasts about fifty-six seconds, after which oxygen must reach the lungs, or death from asphyxia will result. Cold-blooded animals can live for about two hours in an atmosphere of nitrous oxide (Buxton). Kappaeler showed that frogs lose their reflexes in a few minutes in nitrous oxide, but retain them for several hours when placed in an indifferent gas, as, for example, nitrogen. Davy found that nitrous oxide has the power of turning out oxygen from water, and Hewitt suggests that accordingly it probably not only prevents the access of oxygen to venous blood, but actually dislodges the oxygen still remaining in the blood of the pulmonary capillaries. Oliver and Garrett found that carbonic acid was present in the blood in small quantities as compared with the amounts met with during anæsthesia from other agents, but in a large quantity relatively to the amount of oxygen.[3]

The *blood pressure* is raised during nitrous oxide narcosis, but if oxygen is inhaled immediately beforehand the blood pressure scarcely rises during the nitrous oxide inhalations. According to Kemp, the heart beats more strongly under nitrous oxide and air than under nitrogen and air, as if the gas had a stimulating effect upon that organ. When pure nitrous oxide is given to an extreme degree the blood pressure falls, not, however, probably through any

[1] *Amer. Journal of Surgery*, Anæsthetics Supplement, 1917, Vol. 31, p. 66.
[2] Hewitt's "Anæsthetics," 1912, p. 90.
[3] *Lancet*, Sept. 9, 1893, p. 625.

direct action of the gas on the heart, but owing to impeded pulmonary circulation, which entails a fall in the systemic pressure. When animals are killed experimentally by nitrous oxide the heart generally goes on beating after the breathing has entirely stopped. *Post mortem* the heart has the usual appearance associated with asphyxia, a full right and almost empty left side. Any asphyxial element introduced into the administration of nitrous oxide exaggerates the rise of blood pressure. On the other hand, when the gas is given in conjunction with oxygen the blood pressure is only slightly or not at all raised. Similarly the *breathing*, which with pure nitrous oxide is exaggerated, is of a quieter, nearly normal character when sufficient oxygen is supplied along with the anæsthetic. The first effect of nitrous oxide in sufficient concentration is to stimulate the respiratory centre. Later the depth of the respirations lessens.[1] If inhalation of pure nitrous oxide is prolonged the respirations become slow and shallow before finally ceasing. The complete arrest of breathing when brought about by nitrous oxide is generally due to muscular spasm.

The effects of nitrous oxide on the *glandular organs*, if any, have not been ascertained, except in the case of the *kidney*. Kemp [2] describes contraction of the renal vessels and diminution of the secretion of urine with slight production of albuminuria. It is most unlikely that nitrous oxide, when given in such a way as to avoid anoxæmia, produces any tissue changes or even functional derangement in most of the organs of the body.

The advantages which nitrous oxide possesses over the other common anæsthetics, due to its being non-poisonous, make it highly desirable that its defects should be overcome. The chief defect under which it labours is its inability to produce muscular relaxation, at any rate to a degree to be relied upon for abdominal work. Bert [3] observed that complete relaxation could be produced in a dog by putting it in a pressure chamber filled with a mixture of N_2O and O_2, five parts to one, under a plus pressure of one-sixth atmosphere. Without pressure deep anæsthesia from nitrous oxide is impossible without partial asphyxiation, at least in animals. Dale and Hill [4] showed that a mixture of N_2O and oxygen, eight parts to one, which produced, with a ventilation of two litres per minute, an asphyxial anæsthesia with relaxation, was able to produce, when given in a pressure chamber, an anæsthesia equally deep without any deficiency of oxygenation. They suggest that for human beings an operating room with a pressure

[1] *Amer. Journal of Surgery*, Anæsthetics Supplement, 1917, Vol. 31, p. 66.
[2] *N.Y. Med. Journal*, November, 1899.
[3] *Compt. Rend. Acad. d. Sci.*, 1878, Vol. 87, p. 728.
[4] *Lancet*, Aug. 13, 1921, p. 327.

of one and a half instead of one atmosphere would give, with mixtures of N_2O and oxygen from four to six to one, deep anæsthesia with freedom from symptoms of after-poisoning and from shock. McKesson's method of producing relaxation by "secondary saturation" is described on p. 186.

The physiological action of **ethyl chloride** on most of the organs of the body is naturally slight, owing to its extreme volatility and to its poor solubility in blood serum. Also, as its use is mostly confined to short administrations, there is little evidence of effects which might perhaps ensue if it was inhaled for long periods of time. Jaundice has been reported, according to Gwathmey, in a few cases, also albuminuria and fatty degeneration of the kidneys. Evidence is wanting of any influence upon the *blood.* According to Müller, a small amount only is taken up by the corpuscles, and on account of the slight solubility in blood serum a highly concentrated vapour of ethyl chloride must be taken to the lungs to ensure narcosis. A mixture of 10 per cent. ethyl chloride with 90 per cent. air caused narcosis in small animals after six or seven minutes; 50 per cent. mixture caused narcosis rapidly.[1] The concentration of ethyl chloride in the blood of the pig and the mouse at the occurrence of narcosis has been shown to be 0·010 per cent.[2] The effect upon the *heart* and *vascular system* generally is comparable to that of chloroform, but far higher percentages of vapour are required to bring it about. Thus Embley found that the effect of ethyl chloride on the heart muscle is paralytic, but the quantity of vapour required in the air inhaled is nineteen times as great as that of chloroform needed to produce similar results.[3]

The *fall of blood pressure* produced by ethyl chloride is its most notable physiological quality. This fall occurs even in short administrations. Embley states that vagus inhibition of the heart occurs readily in the presence of a vapour of 10 per cent. strength or more, and that with a vapour of 30 per cent. or more the fall of blood pressure is due to weakening of the heart's muscle. This observer found that respiration ceased as blood pressure fell and rose as the pressure rose. He does not believe that the respiration may be paralysed independently of the fall of blood pressure. The rate and extent of the respiratory movements are at first increased by ethyl chloride. The fall of blood pressure which occurs during the inhalation of ethyl chloride is probably chiefly caused by a general dilatation of the arterial system, and this is shown clinically by the flushing of the face,

[1] Hewitt, *loc. cit.*, p. 127.
[2] *Biochemisch. Zeitschrift*, Vol. 40, 1912, p. 29.
[3] Gwathmey's "Anæsthesia," p. 259.

which is a constant symptom in the human subject. If an overdose is administered the flushing is replaced by the pallor of circulatory failure, with widely dilated pupils, flaccid muscles, and stopping of the breathing. According to experiments carried out by Lotheissen,[1] ethyl chloride is not expired undecomposed, the chlorine never being recoverable from the expired air. The elimination of ethyl chloride takes place almost entirely through the lungs. Its solubility in the lipoid constituents of protoplasm appears to be much less than that of ether and chloroform, so that accumulation in the cells of the body tissues does not occur, and consequently prolonged after-effects are unusual.

The *muscular* system is generally, but not always, relaxed during full narcosis from ethyl chloride. Spasm of the muscles of the jaw is particularly apt to persist. The *globes of the eye* roll upwards, and the pupils are dilated. Victor Fielden [2] carried out a number of experiments on frogs and on mammals in order to ascertain the effect of ethyl chloride with air, with oxygen and with carbon dioxide on blood pressure, respiration and the heart. Effects were estimated with vagi cut and intact, and the effect of the drug on the heart and on the blood vessels was tried by perfusion as well as by inhalation. The general conclusion as regards blood pressure was that an initial rise occurs with various concentrations of vapour. With weak vapours good pressure was maintained throughout administrations lasting several minutes, but higher percentages caused a fall which was more rapid the more profound the concentration. These results agreed with those of Embley, Webster and Cole. The experiments showed a beneficial effect of combining oxygen with ethyl chloride, blood pressure being then maintained during a longer time than was possible with the same strength of ethyl chloride without oxygen. Carbon dioxide sometimes increased or maintained blood pressure for a time, but, except in very small proportions, it ultimately caused a more rapid fall than was caused by ethyl chloride alone. The blood pressure was found to be directly dependent upon the condition of the heart. On *respiration* Fielden found ethyl chloride to have an initial stimulant action. The more concentrated the vapour the sooner was this initial effect replaced by respiratory failure and paralysis. Respiration ceased before the heart beat. Cole also found that " with large doses the diaphragm is finally brought to a standstill, remaining in a state of strong tonic contraction until death, the heart still beating strongly." The *heart muscle* was found to be directly affected by ethyl chloride. The initial stimulation soon passes off, and is followed

[1] Gwathmey's " Anæsthesia," p. 263.
[2] " A Contribution to the Pharmacology of Ethyl Chloride," Belfast, 1912.

by cardiac weakening and dilatation. The vagi are not paralysed by ethyl chloride.

Amylene was investigated by Snow,[1] who found its vapour to be almost entirely without pungency and the liquid itself devoid of any irritating effect upon the skin. The vapour is not irritating to the air passages. A vapour of about 10 per cent. was required to produce insensibility in small animals, and Snow reckoned that about one-tenth as much vapour as the blood could dissolve must be absorbed in order to procure the second degree of narcosis. In the case of chloroform he showed the proportion to be one fifty-sixth. At the same time, amylene having a very slight solubility, the total actually absorbed is a very small amount, in spite of its proportion being so large in relation to the whole quantity which the blood would dissolve. Snow calculated that the third degree of narcotism required the presence of a little over 2 grains of amylene in the system, and that it took from 3 to 4 fluid drachms to cause insensibility in the adult. He states that, " viewed in the light of the small quantity which requires to be absorbed into the system to cause insensibility, amylene is a very powerful agent ; but when considered in relation to the quantity which is consumed during inhalation in the ordinary way it is very far from being powerful. This arises from the great tension and small solubility of the vapour, in consequence of which it is, with the exception of a small fixation, expelled from the lungs again without being absorbed." Snow found a vapour of 15 per cent. with air to be suitable for surgical anæsthesia, and that a vapour of 40 per cent. would be needed to paralyse the heart. He did not regard amylene as certain to produce muscular relaxation. He noted that the *conjunctival reflex* was often brisk, while there was no evidence of sensibility to the knife. The *pulse* is increased in force and frequency during the inhalation of amylene and the *respiration* generally quickened. The pupils remain sensitive to light and not dilated, except with strong vapours. Amylene does not stimulate the flow of *saliva* or *mucus*. In fatal cases the respiration has continued several minutes after the heart has ceased to beat effectually.

Ethyl bromide is similar in its action to ethyl chloride, but is more irritating to the air passages. It produces unconsciousness with great rapidity. The respiration is said to be paralysed about the same time as the reflexes, allowing a very narrow margin of safety. Richardson found that when death was induced by ethyl bromide in animals the respiration and circulation failed together. He stated that the vapour strength needed for narcosis was 5 to 10 per cent. Dastre stated that the drug did not lead to " primary

[1] Snow, " On Anæsthetics," pp. 373 *et seq.*

syncope," and he believed that the cerebral hemispheres, bulb, and spinal cord were peculiarly sensitive to the action of the drug, for which reason excitement was commonly absent in the induction of anæsthesia by ethyl bromide. Ginsberg found that small doses of the drug did not lower the blood pressure, and that death was brought about by respiratory failure before cessation of the heart beat. Cole [1] found that the strength of the heart beat was diminished whether the vagi were cut or intact, and that the vagus endings in the cardiac ganglia were paralysed. The rate of the heart's action was increased and rigidity of the skeletal muscles occurred even in deep narcosis. Webster [2] disagreed with this opinion as to the effect of ethyl bromide on the terminations of the vagi, and stated that full vagal effects could be obtained with an animal completely anæsthetic under ethyl bromide.

Amyl hydride was found by Richardson to give a vapour capable of producing anæsthesia very rapidly. This was preceded by spasmodic movements and followed by rapid recovery. The heart is easily paralysed by the vapour. It was necessary for anæsthesia to provide a vapour of 40 per cent. with air, and 6 to 12 drachms of the liquid were needed.

Ethidene dichloride, which, under the name of "monochlorinetted chloride of ethyl," had been used as an anæsthetic by Snow, was experimentally investigated by the Glasgow Committee. The drug was found to have a depressant effect on the heart and to lower the blood pressure, its action in these respects not being, however, so powerful as that of chloroform. It produces muscular rigidity and is slower than chloroform in inducing unconsciousness.

Dutch liquid, which, according to Snow, has the same composition as the above, but a different boiling point, was found by the Glasgow Committee to produce convulsions before true anæsthesia.[3] It had been previously tried by Simpson, Snow and Clover, and by Richardson, who found that 2 to 8 drachms were needed for complete anæsthesia, and that the strength of vapour necessary was 5 to 10 per cent. with air.

The Glasgow Committee [4] found that *butyl chloride* caused breathing to cease soon after anæsthesia was reached, that *acetone* caused only slight effects in the frog even after long administration, and that *benzene* caused struggling and cardiac weakening.

Isobutyl chloride was found capable of inducing anæsthesia

[1] *Brit. Med. Journal*, June 20, 1903, p. 1423.

[2] *Lancet*, July 14, 1906, p. 106.

[3] *Brit. Med. Journal*, Jan. 4, 1879, p. 1.

[4] Hewitt, *loc. cit.*, p. 130. Most of the immediately following information is from the same source.

in rabbits and dogs in three to five minutes, and breathing was unaffected after half an hour's inhalation. With human beings it produced excitement without satisfactory narcosis.

Methyl chloride was found powerless to procure more than drowsiness, rabbits which were experimented on preserving their reflexes after long administration.

Tetrachloride of carbon has been found capable of producing anæsthesia in animals. Excitement and muscular spasm occur early in the narcosis, followed by a lowering of the blood pressure during anæsthesia. Richardson found 5 to 10 per cent. to be the necessary strength of vapour. Anæsthesia was very slow in being attained, and recovery very prolonged. The temperature fell 4° F. during anæsthesia. The vapour is more irritating to the air passages than that of chloroform. It has been stated to be a more powerful heart depressant than chloroform, but Cushing describes it as only half as powerful (Gwathmey).

Carbon monoxide has been tried experimentally as an anæsthetic for animals. Richardson found that 5 per cent. in air caused rapid anæsthesia with convulsions and a fall of temperature of 2° F. Its known danger to human beings renders it impracticable.

Carbon dioxide was experimented with by Hickman, Nunneley, Snow and Richardson. The last named found that air containing 25 per cent. produced rapid insensibility, which was accompanied by convulsive action, asphyxia, and fall of temperature. Gwathmey refers to a case in which an abscess was operated on under anæsthesia produced by a vapour of 75 per cent. carbon dioxide with 25 per cent. air. Gréhaut recommended a mixture of 45 per cent. carbon dioxide with a proportion of oxygen equal to or greater than that in atmospheric air. With this mixture rabbits were deeply narcotized in two minutes, and anæsthesia could be maintained for a long time. Respiration was much slowed, but its rhythm unaffected. Blood analyses showed that the oxygen percentage remained constant, but that the carbon dioxide was greatly increased, varying between 80 and 90 per cent. Richet pointed out that carbonic acid is not eliminated so rapidly as many other anæsthetics because it plays the part of an acid while within the organism and combines with the alkalies of the blood and tissues.

Carbon disulphide, which was tried clinically both by Simpson and Nunneley, was also investigated by Richardson, who found that a 10 per cent. vapour was needed and that 4 to 8 drachms produced anæsthesia. He found that when death was brought about the circulation outlived the respiration.

Methylene, or *bichloride of methylene* (CH_2Cl_2), was introduced

by Richardson. The quantity of liquid necessary to produce anæsthesia he found to be 1 to 6 drachms and the strength of vapour in air 5 to 10 per cent. The action was rapid, with short but acute spasmodic stage.

Richardson also used *methylene ether*, a mixture of equal parts of absolute ether and methylene. When animals were killed by the vapour of this mixture the respiration ceased before the circulation.

Acetate of ethyl, or *acetic ether*, has been used, according to Hewitt, for producing anæsthesia in the frog. For the mention of many other substances which have been tried experimentally as anæsthetics the reader is referred to a full list in Gwathmey's "Anæsthesia" (1914).

Mixtures of anæsthetics have been subjected to a little physiological experiment. The most important of these relate to the C.E. mixture, consisting of two parts of chloroform to three of ether by volume. According to Schäfer and Shirley,[1] the ether here acts merely as a diluent, the mixture behaving precisely like chloroform of the same strength. On the other hand, in the A.C.E. mixture they attribute much value to the alcohol ingredient (16·5 per cent.), the ether again being, so far as effect on blood pressure goes, a negligible quantity. Kemp[2] found that vapour of C.E. mixture given to dogs with 95 per cent. of air produced results similar to those of chloroform, estimated both by blood pressure tracings and by effects on the kidney. Leonard Hill found that, introduced intravenously, the mixture produced first an ether and then a chloroform effect.

[1] Buxton's "Anæsthetics," 1920, p. 343.
[2] Hewitt, *loc. cit.*, p. 132.

CHAPTER VIII

ADMINISTRATION OF ANÆSTHETICS

Accessory Conditions—Examination and Preparation of the Patient—Management of Children—Implements and Arrangements

THE aim of the anæsthetist has widened from the mere desire to produce oblivion to pain during operation. His object now is to arrange that the patient shall approach the operation with a quiet mind free from apprehension, that he shall pass through it in complete unconsciousness and in a condition which gives the surgeon the greatest possible facility for his manipulations, and, finally, that he shall recover consciousness free from pain or sickness or other discomfort and in the best possible position to allow of uninterrupted convalescence. Some years ago Mr. Bernard Shaw scoffed at anæsthesia as "sparing us nothing but the actual cut." That reproach does not hold good of the well-trained administrator to-day. Such a man will not only employ the necessary knowledge and skill for producing perfect anæsthesia during the operation, but he will take the necessary measures both before and after it to save his patient from dangers and from discomforts. To do this he will have to pay attention, with other things, to the accessory conditions of an operation. These are most easily controlled and perfected in hospitals and similar institutions, and it is in private houses that the directions of the anæsthetist are most often required in order to secure the best possible circumstances for the patient. The choice and preparation of the room will be no part of his business, but he must see to it that the temperature is unobjectionable and that general arrangements are correct. Thus he may be called upon to see whether the anæsthetic is to be administered to the patient in bed or after he has been transferred to the table on which operation is to take place. For some operations it is not necessary to move the patient from his bed at all, and then proceedings are much simplified. This occurs, generally speaking, only in the case of minor operations, some obstetric procedures, and of painful dressings. Minor rectal operations in particular can be most conveniently carried out in this way, the patient being placed

well on one side, the buttocks overhanging the edge of the bed. The late Herbert Allingham preferred this position in bed for his operations for piles, and there is no doubt that it offers great advantages in saving of time and in minimizing the amount of movement applied to the patient. At the end of operation he is merely lifted further into the bed. The technique of modern surgical cleanliness, however, is not conveniently carried out at the bedside, and this has led to the disuse of Allingham's practice. Lumbar puncture offers another example of a small surgical procedure for which an anæsthetic to the patient in his bed is sometimes required. Here the patient is often delirious or restless, the subject, for instance, of cerebro-spinal meningitis or some other cerebral condition rendering the puncture necessary for diagnosis or treatment. It is far better to offer the anæsthetic to such a patient in bed and with the least disturbance possible than to have him moved on to an operating table. The less a patient is moved when he is under an anæsthetic the better. Consequently the best arrangement of all is that which holds in most hospitals. The patient lies upon the table on which he is to be while under operation, but in a room adjoining the operating theatre. When unconscious he is wheeled into the theatre. The next best way is for the patient to lie upon a stretcher placed on his bed. Here he takes the anæsthetic, and when narcotized is moved on the stretcher to the operating table. In private houses these measures cannot be generally imitated, and the question arises, Shall he be placed on the operating table before or after he is unconscious? When he is in such a condition that he can without pain or detriment to his ailment either get on the table himself or be carried there, it is better that he should do so and have the anæsthetic administered there. Instruments will be covered with sterilized towels, and there will be no talking or bustling about of nurses or assistants to distract or puzzle the patient's mind while he goes through the early stages of narcosis. Generally it is best if besides the anæsthetist there is no one near but the surgeon, whose presence is a comfort to the patient with whom he is already acquainted. When moving the conscious patient would give him pain or expose him to extra risk, he must be given the anæsthetic in bed and afterwards carried to the operating table. It is important that when this has to be done the patient should be quite fully narcotized first, otherwise the moving will cause him to vomit or to strain or partly to regain consciousness, all of which are undesirable. Before starting the anæsthetic the anæsthetist will note carefully the relative positions of the bed and the operating table, which are preferably in different rooms, in order that when the move is carried out all those who

lift the patient may stand on the correct side. They should so arrange themselves all on the same side of the patient that when they lift him and place his head at a right angle with the foot end of the table they are between this and the bed. They have then only to make a short turn to deposit their burden on the table. The patient, whether in bed or on an operating table, should always be allowed to keep the position in which he breathes most comfortably while he inhales the anæsthetic. Any alteration necessary for the surgeon can be made after narcosis is established. There are two classes of patient with whom the general rule should be reversed that it is better to place the patient on the operating table before giving the anæsthetic. These classes are children and very nervous, frightened women. Occasionally men partake of the characteristics of these classes, and must be treated as though belonging to them. For all such individuals the ordeal is greatly mitigated if they lie in bed till the time for operation approaches and then receive the anæsthetic in bed with the least disturbance possible. Wherever the induction of anæsthesia is carried out, whether in private bedroom, hospital anæsthetizing room, or the theatre of a nursing home, it is most desirable that quiet should be observed. Everything should tend to encourage in the patient the idea suggested to him by the anæsthetist that he will fall easily to sleep. In the early stages of narcosis the special senses are perhaps heightened in receptivity, and certainly control by will is lessened. Imagination thus easily runs riot, and it can well be supposed how easily the sound of moving instruments or the relation in too unsubdued a tone of some recent surgical triumph may in the ill-ordered thoughts of the semi-conscious patient give rise to horrible ideas of personal danger. His hearing is acute, and is the last sense to leave him ; but his eyes, too, must not be forgotten, and there must be nothing visible to him that might upset his perturbed mentality. No glittering array of instruments and no face that expresses an anxious anticipation of trouble should be the thing of which his declining consciousness has its last cognizance. Let him be lured to oblivion gazing only on objects that appear harmless and persons who appear cheerful, quiet and confident, if they appear at all. **The child** may lie in bed nursing its favourite toy or listening to a story read by its mother or other familiar companion. Unless too young to understand, it will have been told merely that it would be staying in bed that day as it was to have some scent given it by the doctor in order to be " made well." Thus the gradual administration of this scent, accompanied by the mother's talk, will give the young patient no alarm, and the whole experience will allow future ideas of operation to be unaccompanied by any terror in

the mind of the child, a not unimportant matter in its later years. The less said to a child beforehand the better, but at the same time there should be no attempt to take it by surprise if it is old enough to understand. It will, from the absence of its breakfast or from the presence of a strange nurse or the rearrangement of a room, have guessed that something unusual is to take place. Far better, then, to explain briefly and simply why these things are happening, and what is expected of the patient, than to attempt, so to speak, to "rush" him. If deceived or surprised the child will be unforgiving and suspicious afterwards. In the management of highly apprehensive women preliminary narcotics are of great service; their use is fully considered in Chapter XVI.

The *atmospheric conditions* under which an anæsthetic is taken play some part in determining the effect produced. Paul Bert showed that if atmospheric pressure is artificially raised the effects of an anæsthetic are heightened. We should expect, therefore, a corresponding diminution in effect if the inhalation took place in a mountainous resort or elsewhere in a rarefied atmosphere. The day may come when such a consideration will affect the actions of the administrator in an airship hospital, but at the present day the barometric pressure does not demand serious consideration. At the same time, some observers declare their ability to notice a difference in the behaviour of patients under nitrous oxide in accordance with a high or low barometer. Warmth and dryness of the air are more important. Generally speaking, anæsthesia is more easily obtained in summer than winter. The volatile anæsthetics are more easily vaporized and also more easily eliminated in a high temperature. The absence of catarrhal affections of the nose and throat, which easily cause difficulties of inhalation, is another factor favourable in the warmer months. It is often stated that ether cannot be used in India. The author is assured by men who have worked there that, on the contrary, in most stations it can be employed during the greater part of the year. Care, of course, is needed in the keeping. The extra safety sometimes claimed for chloroform in India is attributed to its ready volatilization and elimination in the warm climate. The exemption from fatalities, however, that is sometimes reported from tropical countries is not borne out by the accounts of trustworthy and widely experienced observers. A recent writer, recounting [1] his experiences with anæsthetics given to British troops in India, bears out the above opinions. In Bombay and up country in dry climates with a temperature of 100° F. he used open ether satisfactorily. Mixtures also he found

[1] *British Med. Journal*, Oct. 11, 1919, p. 464.

quite suitable, and he deprecates routine use of chloroform in the tropics.

The **temperature of anæsthetizing and operating rooms** should be 65° to 70° F. Some surgeons prefer a much warmer theatre than this. That, however, leads to discomfort, perspiration, and fatigue on the part of all working in the heated atmosphere. It is important, of course, that all should be done possible to conserve the body heat of the patient. This is better achieved by supplying extra warmth to the table on which he lies than by overheating the atmosphere of the theatre. The coverings of the patient should be loose and warm. Woollen stockings reaching the thigh and flannel pyjamas are most suitable. Over these a blanket is placed, and warmth is thus provided for all parts that have not to be exposed for the operation. When the condition of the patient or the severity of the operation demands extra measures to conserve heat, the limbs should be completely swathed in cotton-wool and lightly bandaged from below upwards and the chest and abdomen similarly covered with wool as far as is possible. The effect of using warmed vapours in helping to conserve the body heat is considered elsewhere (p. 118). It sometimes becomes necessary to give an anæsthetic in a dark room in order that the X-ray screen may be employed. Under these circumstances the anæsthetist has to guide himself entirely by the sound and feel of the patient's respiratory movements. If the proceeding is at all prolonged a drop bottle and mask are not to be used, for in the absence of light this method is risky. A Clover's inhaler or a Shipway's apparatus, according to the needs of the case, has always been found safe and suitable. Guedel has described an auscultatory tube which allows the anæsthetist good control of the patient by hearing. He states that with this instrument it is possible to tell in the dark whether the breathing is oral or nasal, whether swallowing is going on, whether mucus is entering the larynx, or whether there is the least effort to cough or to vomit. It must be admitted, however, that these phenomena can generally be detected in the dark room without adventitious aid if the anæsthetist has good sense of hearing and of touch and rivets his attention upon the patient.

Examination of the Patient.—It is not usual at the present time for the anæsthetist to see a patient till shortly before giving him the anæsthetic. There are, however, great advantages in the opposite practice, and whenever possible the anæsthetist should see the patient a day or two beforehand. Most persons will be relieved of much anxiety if they are confronted on the day of operation with some one who is not a total stranger and in whom they have already learned to repose confidence The anæsthetist

on his part will have had time thoroughly to consider the best procedure to adopt in view of all he has discovered about the patient. When the patient's condition is grave the anæsthetist should always be given an opportunity of seeing him before the time comes for operation. The question will probably arise as to the patient's ability to go through an operation at all, and it is only fitting that the man who will be responsible for bringing the anæsthesia to a safe conclusion should be allowed to form his own opinion of the possibility of this. Often in these conditions the anæsthetist will find himself able to state time limitations for the operation. He will feel confident of bringing the patient through an anæsthesia of half an hour, for example, but will not guarantee more. It is scarcely ever that he will find it necessary to refuse an anæsthetic when the surgeon wishes to operate. If a patient can stand the operation, he can stand the anæsthetic almost without exception. Whether or not he has been able to interview the patient himself, the anæsthetist must be informed of the patient's general history and condition and of anything abnormal that may be present. Thus the chest will have been examined, the urine will have been tested for sugar, albumen and acetone, the blood pressure ascertained, and any suggestion of abnormality of the blood will have been tested by microscopic examination and hæmoglobin tests. In hospital these measures are carried out in routine fashion, and nothing abnormal being reported to the anæsthetist, he knows that he has an ordinary individual to deal with. In private practice the same preliminary knowledge is afforded by the practitioner or the surgeon who has engaged the anæsthetist. The latter then, as in hospital, makes before the operation, supposing that he has not seen the patient beforehand, a routine superficial examination. He listens to the heart and breath sounds, feels the pulse, tests the respiratory movement by a hand on each side of the chest while the patient breathes deeply once or twice, and he inspects the inside of the mouth. No more elaborate investigation is needed or advisable just before operation.

A good deal of **important information** is gathered by mere **inspection**. Chronic alcoholism can generally be detected by its effect on the complexion, if it does not show in the tremulous manner or is not discernible in the breath. The secret drinker will often be a pale, unhealthy-coloured, thin woman, and her vice may have been only suspected hitherto. The suspicion will almost inevitably be turned into certainty by her behaviour during the induction of anæsthesia. If the patient is up and about when first seen his movements give a general idea of his fitness and activity. Any shortness of breath that they

bring on will lead to an investigation as to its cause. Inspection of the recumbent patient will show whether the breathing is carried out mostly by the diaphragm or whether the chest is still elastic and working well. Note is made of the position which the patient naturally assumes and in which he breathes most easily. If he can breathe comfortably only on one side or in a propped-up position, the reason for this is ascertained and has direct influence on the choice of anæsthetic and method of giving it. The patient's ability to breathe through his nose should be tested. Any hoarseness or cough will be noticed and its cause ascertained. Mere inspection shows the experienced anæsthetist almost at a glance whether the patient will be easy or difficult to manage. Confronted with a large, fat individual with full red face, several chins, short neck, and a pendulous abdomen, the anæsthetist is forewarned, and it will be his own fault if he is not also forearmed when the administration begins. An individual of this kind will need much anæsthetic and much air. He will with difficulty be kept free from cyanosis. On the other hand, the small pale woman may offer the preliminary obstacles of nervousness and apprehension, but will otherwise be an easy subject, with whom the chief care will be not to use too much anæsthetic. The ordinarily healthy individual will react to anæsthetics very largely according to his mental disposition, which the anæsthetist must do his best to estimate in the few minutes of preliminary examination. In the case of the highly nervous very much will depend on the manner in which the anæsthetist examines and speaks to the patient. The more he is able to soothe and reassure him, the less likely are difficulties to arise during the administration. On the other hand, to be too fussy is almost as great a blunder as to be too callous. The patient should realize from the way in which he is talked to and handled that the anæsthetist knows his own business thoroughly and is fully concerned with the patient's welfare; in a word, that he is both able and eager to do the best that can be done for him.

When the anæsthetist makes the **examination on some previous day** he is able to test the cardiac efficiency more thoroughly. He can find out also any history showing a tendency to fainting. He will be able to try the patient's ability to hold his breath for half a minute or so and note the effect of this on the rapidity of the pulse. Richardson [1] recommends that three long breaths be drawn and the last one held. If the patient cannot hold his breath for forty seconds, then the cardio-vascular system needs further investigation. Cashman [2] has used a test of the reserve power of the

[1] *Amer. Journal Surgery*, 1919, Vol. 33, p. 109.
[2] *Amer. Journal Med. Sci.*, 1917, Vol. 154, pp. 476—489.

cardio-vascular system depending on the behaviour of the pulse pressure after exercise. In a normal person exertion causes a rise of both systolic and diastolic blood pressure. The diastolic pressure rising less than the systolic, there is an increase in the pulse pressure as compared with that before the exertion. A fall in pulse pressure, whether due to a fall in systolic or a rise in diastolic pressure, shows that there is poor response to strain on the part of the cardio-vascular system, and is generally accompanied by breathlessness, dizziness, or fatigue. In most operations the cardio-vascular system is exposed to strain, and the risk of death from heart failure is increased if the test shows diminution of pulse pressure on mild exertion. The test is carried out thus :—The pulse rate and blood pressures are taken in the recumbent and in the standing positions. Then the patient walks rapidly or uses dumb-bells, and the pulse rate and blood pressures are again taken in the two positions. In persons with cardio-vascular debility the systolic blood pressure falls on changing from the recumbent to the standing position. In normal persons it rises. The pulse pressure, as explained above, rises in healthy persons as a result of the exercises undergone ; in the presence of cardio-vascular insufficiency it falls. Further, the anæsthetist can listen to the heart after the patient has taken brief exercise, as by running up and down stairs, or by bending to touch the toes and rising again several times in rapid succession. It is the efficiency of the cardiac muscle more than any valvular defect that the anæsthetist is anxious about. If his examination leaves him suspicious of the heart he will be wise to recommend that a cardiographic and X-ray examination be carried out, as is done before operating on the subjects of exophthalmic goitre. He must bear in mind that fatalities from anæsthetics have been commonly associated with **fatty and other defects of the cardiac muscle,** which may indeed be guessed at, but are not easily positively diagnosed by ordinary examination. Similarly when dealing with children and young adults the anæsthetist will remember the possibility of the **status lymphaticus** being present, and if he finds anything in the physique to suggest that condition he will endeavour to have the thymus gland and the spleen X-rayed. He will observe the papillæ at the back of the tongue with unusual care in addition to examining the patient for abnormally large lymphatic glands of the neck, groin, or axilla. When inquiring into the previous history of a child he will seek to discover any evidence of cyclical vomiting, the occurrence of which will urge him to special precautions for the avoidance of post-anæsthetic toxæmia.

The Time for Operation.—When there is no urgency and the

most suitable time can be chosen for operation, the best hour to select is in the early morning. The patient's vitality is at its highest after a night's rest ; he is spared the deprivation of a meal and the annoyance of waiting in anticipation of an ordeal. If a time between eight and ten o'clock is chosen there is no need for any food, but if the patient is awake early he may be allowed a cup of tea. Whatever hour is selected, there should be an interval of at least four hours since the last solid food—operation, that is to say, is fixed at about the time when a meal would be taken. In ordinary circumstances there need be no alteration in the usual habits and feeding during the days before operation. When this will entail a long stay in bed it is generally, however, a good thing for the patient to accustom himself to this and to the *régime* of a nursing home by taking to his bed there a couple of days before the day of operation. During this enforced inactivity probably an aperient will be needed. It should not be given later than thirty-six hours before operation, *i.e.*, on the evening of the day before that immediately preceding the operation. Most patients know what aperient drug suits them best, and this will naturally be selected. No enema should be given on the operation morning except before rectal operations. Many people are upset by enemata, and if unaccustomed to them a patient could have no more unsuitable preparation than to be awakened early and subjected to an uncomfortable rectal experience, a practice that was common, but is now fortunately largely abandoned. During the preliminary days in bed the diet will naturally be lighter than if the patient is ordinarily active. Preponderance should be given to the carbohydrate elements, and some fresh fruit should be included. Plenty of water should be drunk during this time, and half a pint may be given an hour before the administration of the anæsthetic. If there is any tendency to sleeplessness bromides should be given on the two nights preceding the operation morning. Particular attention is to be paid to the cleansing of the mouth, the teeth being brushed after every meal on the day before, the mouth well rinsed, and the throat gargled with listerine or some similar antiseptic. Such measures probably help to avoid post-operative sepsis and the occurrence of parotid inflammation during recovery. Post-operative pneumonia [1] is, in the opinion of good authorities, mostly due to septic teeth or a septic state of nasal sinuses. These must be treated before operation whenever time permits Particular preparation is recommended by some surgeons before special operations. The details of this will, however, not be within the province of the anæsthetist. Before stomach

[1] *British Med. Journal,* Jan. 15, 1921.

operations, for instance, some authorities require sterilized food, washing out of the stomach, and other measures. The anæsthetist should in such cases be informed of what has been done before he administers the anæsthetic. When acetone or its precursors, β-oxybutyric acid and the like, are found in the urine, alkalies and glucose are to be given till the excretion is normal. Some surgeons give children glucose as a routine measure during the twenty-four hours preceding operation, or at least encourage an increased consumption of sugar, as by sucking barley-sugar, for a day or two. Adults are given glucose also as a preventive of vomiting by some practitioners. Testing a series of unselected patients in hospital, I was not able to satisfy myself that the administration of glucose beforehand altered the frequency of post-anæsthetic vomiting in adults. A. L. Flemming has shown that the soup or beef-tea customarily given in hospital a few hours before operation is better replaced by milk. Diminution in the frequency of after-sickness followed this alteration in routine when it was tried on a large number of individuals. The result accords with our knowledge of the importance of carbohydrate as compared with protein elements in pre-anæsthetic feeding. Generally speaking, the less alteration that is made in the patient's customary habits and diet the better, so long as care is taken that the alimentary tract is not loaded, and that the bladder also is emptied shortly before operation. This detail should be attended to even before taking a short administration of nitrous oxide. Otherwise the sphincter may relax during unconsciousness, an accident particularly common with children. Although it is not usual to take special measures before "taking gas at the dentist's," it is well that the stomach should be empty as well as the bladder. Vomiting may be caused even by a quite short inhalation if the stomach is full, and the more serious trouble of reflex syncope is also to be feared with that condition present. Although it is desirable that the stomach should be empty at the time of operation, it is important not to starve the patient unduly. There is good reason to believe that in some instances the occurrence of post-anæsthetic toxæmia has been facilitated by starvation, which is in itself a cause of acidosis. The aged and the very young both need special care from this point of view, for neither class stands well a long deprivation of food. To feed the patient too soon before giving the anæsthetic is, however, more likely to bring trouble than leaving him too long unfed. The golden mean will be found by following the general lines laid down above and allowing the operation time roughly to approximate to an ordinary feeding time at the customary interval. Some easily assimilated stimulant, thin, clear soup or tea or brandy and

water, may be allowed to the old and feeble a couple of hours or even less before the administration.

Implements and Arrangements

Besides the apparatus and drugs required there are a few

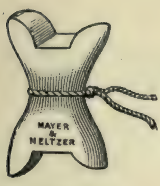


Fig. 1.

Fig. 2.

Fig. 3.

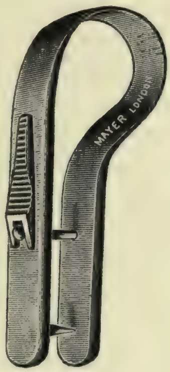


Fig. 4.

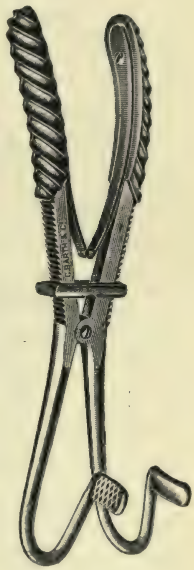


Fig. 5.

Fig. 6.

implements that should always be at hand when an anæsthetic is given. These are :—

(1) Small mouth-prop (Fig. 1) attached by a foot of strong silk to a wooden wedge (Fig. 2). The wedge may be

needed to permit the insertion of a gag. The prop will often be used with advantage during induction or after.

(2) Tongue-forceps to draw forward the tongue and tongue clip to hold it forward if necessary (Figs. 3 and 4).

(3) A coarse-meshed sponge for clearing the fauces and a bowl of water in which to wring this out.

(4) Mason's gag (Fig. 5).

(5) Simple infusion apparatus—funnel, supply tube, and hollow needle.

(6) A cylinder of oxygen.

(7) Hypodermic syringe and ampoules of strychnine, pituitrin, and adrenalin.

(8) Tracheotomy tube and scalpel, and a hand-towel and small empty bowl.

(9) An artificial air-way (Fig. 6).

The stimulating drugs and the hypodermic syringe may be needed for the treatment of surgical shock. The tracheotomy tube will very likely not be used in a lifetime. Yet if the emergency did arise which required it probably a life would be sacrificed by its absence. Therefore it should always be present.

It is interesting to notice the comparative frequency with which tracheotomy was performed in earlier days for the treatment of emergencies during anæsthesia. A better understanding of the true nature of these accidents has led to the reservation of tracheotomy for patients in whom a definite obstruction in the larynx or above it cannot be otherwise overcome—a very rare circumstance during narcosis. In an experience of twenty-five years I have met with no anæsthetic emergency in which tracheotomy would have been helpful. It is probable that tracheotomy was often performed in the past because the few spasmodic gasps that may herald death from chloroform were taken as evidence of respiratory obstruction. Tongue-forceps also are an instrument comparatively rarely wanted. The more expert the anæsthetist the more rarely will he find it necessary to apply tongue-forceps. Generally by proper manipulation of the jaw and use of a prop or an air-way he avoids the necessity for tongue-forceps. Yet there are occasionally patients in whom the forceps must be used in order to get the tongue forward and away from the upper opening of the larynx. When it is necessary to hold the tongue out a clip of the Bellamy Gardner pattern should be used, as this does not damage the tongue, but long application of the forceps will do so. All the anæsthetist's apparatus should be as nearly as possible *surgically clean*. Most of the things that he uses can be sterilized by boiling—metal frames of his masks, his gags,

tongue-forceps, etc. The rubber portions of his *matériel* must be well washed after being used and then rinsed with 1 in 60 carbolic solution or lysol (a drachm to a pint of water). When a closely fitting face-piece is to be used on several occasions in succession the same face-piece should not be used twice running. In hospital dental practice, for example, a face-piece that has just been used should be in cleansing solution while the next patient is being treated with an alternative face-piece. The risk must be remembered of conveying disease from one patient to the next if this precaution is not taken. When re-breathing has been permitted the bag must be cleaned before it is used for another patient. It should be filled with weak carbolic solution and then emptied and allowed to dry. Similarly, the small bag of a Clover's inhaler must be washed out with water after use. The chance of conveying disease is here, however, considerably less than in the case of a "gas" bag, because of the germicidal properties of ether vapour. Needless to say, the anæsthetist's hands should be scrupulously clean, and he will wear a gown, cap, and face-mask unless circumstances make this unnecessary. The gown may be worn from the first, but the cap and face-mask need not be put on till the patient is unconscious.

A few general rules may now be stated that apply whatever the anæsthetic to be administered. The patient having been examined in accordance with the views given on pp. 96 and 97, lies, whenever circumstances permit, on his back with the head slightly raised and turned to one side. During operation it should be turned, whenever possible, away from the side on which the operator stands. At the start the head may be as high as the patient prefers. Most people are more comfortable if it is higher than it is advisable to keep it during anæsthesia. If nasal respiration is not perfectly free, or if the teeth meet accurately and without gaps, a small prop should be placed between the teeth on one side before the administration begins. This is attached by a foot of strong silk or twine to another prop or to the wooden wedge (see Figs. 1 and 2), in order that there may be no possibility of swallowing the prop. The anæsthetist stands behind the patient's head. All the things that he may want are within easy reach behind the right side. He will remember that the success of the administration will depend largely on attention to detail and to concentrating absolutely on what he is doing and the effects that this produces. He will keep himself informed of the operator's progress, but otherwise he will occupy himself entirely with his own work and the patient's condition, and he will enter into no conversation. The importance of quiet during induction has already been stated (p. 93). During induction he will talk

or not and encourage the patient, according to his reading of the patient's temperament and needs. Some persons prefer absolute quiet while they "go off"; others beg to be spoken to as long as they can hear. Generally, very little need be said beyond the assurance that the patient is doing well and that all is going on satisfactorily. Any excited movement should be restrained only sufficiently to prevent damage to the patient by himself, and to the bystander. It is bad practice to try and hold the patient down entirely or to keep his limbs absolutely immobile if excitement begins. He must be allowed play if he moves about, and the anæsthetist must accommodate himself to the shifting position of the patient's head. Very rarely there will be wilful struggling, generally on the part of a hospital patient or a spoilt child, and then a short application of force may be needed.

CHAPTER IX

ADMINISTRATION OF ETHER AND OF ETHANESAL

Ether can be given along several routes and by a variety of methods. Its entry into the circulation may be effected *viâ* the lungs, veins, the rectum, the mouth or intra-muscularly. The methods which we must consider are :—

(1) Inhalation :
   (*a*) Open—(1) drop, (2) vapour ;
   (*b*) Semi-open method ;
   (*c*) Closed method.
(2) Intra-tracheal insufflation ; intra-pharyngeal insufflation.
(3) Rectal injection.
(4) Infusion into veins.
(5) Oral administration, by swallowing.
(6) Intra-muscular injection and subcutaneous injection.

In the use of all these methods ether may be preceded by sedative drugs. The inhalation methods are often begun by inducing anæsthesia with nitrous oxide, ethyl chloride, chloroform or its mixtures.

Generally speaking, the *inhalation methods* are both more convenient and more suitable than the others, but under special circumstances one or other of these may be the method of choice. The occasions when this is so are described in the pages dealing with the choice of anæsthetic.

Open methods of administration are those in which the anæsthetic is inhaled from a mask of some porous material on to which it is dropped or poured, or else from a tube along which the vapour is pumped with a current of air. This tube may be fitted on to an open mask from which the patient finally receives the vapour, or else the tube may itself be placed in the mouth or nose, or in the top of a tracheotomy tube, as the case may be. Exception has been taken to the use of the term " open ether," inasmuch as there is no perfectly free access to the air when a so-called " open " mask is used, since the mask is allowed to rest upon the face. This seems hair-splitting. The term " open " denotes the contrast with closed methods, which are carried out by means of a close-fitting face-piece and a bag. Here there is re-breathing and no escape for the expirations comparable to that provided

by the open method. Moreover, most of the closed apparatus necessitates breathing through a more or less restricted channel, and is thus in a sense closed even when the re-breathing bag is removed. At least, such an arrangement is closed in comparison with the freedom of an "open" mask. Those who object to the word "open" as applied to the open method of giving ether would apply the term only to a method by which the patient has perfectly free access to the air. For example, when chloroform is given by mask and drop bottle and the mask is never allowed to touch the face, the patient inhales from and exhales into an atmosphere which is unseparated from the general air. This is truly open. When the mask is on the face and the vapour it yields is breathed through it, the term "perhalation" is proposed as more accurate than "open." It appears, however, that no confusion will arise and that we shall be spared an extra compound word if we continue to use the term "open" for all those methods to which it is commonly applied—methods, that is to say, in which no closed apparatus is employed and the respirations pass freely through the material carrying the anæsthetic.

The term "semi-open" can rightly be applied to apparatus which, although not closed, yet curtails the air supply in a way which the open mask does not. The Allis and Rendle inhalers are examples.

The open and the closed methods of giving ether present certain respective advantages and defects, and may be broadly contrasted. The open have the advantage that they are less likely to be associated with asphyxial symptoms, with violent respiratory movements, with much congestion and with mucous and salivary secretion. Moreover, after-effects are less severe. On the other hand, induction requires a longer time, and with difficult subjects it may be impossible to obtain a sufficiently deep degree of narcosis for some operations. The amounts of ether expended are also greater. The closed methods are more rapid, and, since they provide a more concentrated vapour, are more powerful. They are, however, more likely to cause congestion, mucous and salivary secretion, exaggerated breathing, and muscular spasm. Generally speaking, closed methods should be used only for comparatively short operations. They should not be employed for abdominal operations, in the case of feeble individuals, or for those with any respiratory affection. Those who disapprove altogether of closed methods have condemned the bag as a probable source of infection. There is, however, no good evidence that damage is done by inhalation from a closed bag, and the strong germicidal properties of ether vapour make it unlikely that organisms flourish in these

receptacles. Moreover, the rubber surface provides a most unsuitable medium for organic growth, and the temperature during disuse would be equally unfavourable. The re-breathing, which is part of the process, ensures a warming of the vapour inhaled and is preventive of any undesirable effects attributable to acapnia. The pallor, sweating, and feebleness sometimes present at the close of long operations under open ether are attributed by some authorities to the deficiency of carbon dioxide in the circulation brought about by the method. According to these observers, there is a condition of carbon dioxide deficit, for the excretion of this gas is lowered during any form of anæsthesia, and the open method does nothing to conserve it, but, on the other hand, increases the facility with which it is eliminated, particularly if there is a marked excitement stage with forced respiration. The occurrence of acapnia and the symptoms attributable to it are prevented by re-breathing. Re-breathing, on the other hand, develops cyanosis unless oxygen is supplied in sufficient quantity. When this is done the respiratory centre is not deprived during a closed administration of the carbon dioxide, which is normally its chief chemical stimulus to activity, nor are the tissues deprived of their due oxygenation.[1] Induction by closed methods is more rapid than by the open varieties. The former lend themselves more easily to the initial use of gas or ethyl chloride, and in this way they are made more rapid still. This is often an advantage with nervous individuals. On the other hand, some of these people dread, above all things, the close application of a face-piece, a necessary part of the closed procedures. The apparatus required, which is of the simplest kind for the open method, is rather more complicated for the closed, particularly if this is preceded by nitrous oxide. Moreover, skill in the use of the latter is acquired only by considerably more practice than is necessary for proficiency with the open method. Broadly speaking, it may be laid down that closed methods should be reserved for short operations on healthy subjects ; open drop methods may be used for all, but have their especial field in the feeble and in abdominal operations. Lung affections are less common after open administrations, and the taste of ether is not so tenaciously implanted as it is after closed inhalations.

The open method by means of **drop bottle and mask** is the simplest form of ether administration. It is also very free from danger. Over-dosage is more difficult to bring about than with closed inhalers, and also the asphyxial factor is absent. The method is said to have been used for many years in the north of

[1] *Journal Amer. Med. Assoc.*, Vol. 65, No. 1, pp. 2—5.

England. It was first brought into notice, however, in America, where Prince [1] described the technique in 1896, and where Ferguson, of Boston, was one of its earliest advocates. Some years later Dr. Ferguson kindly demonstrated the use of his mask to me at St. George's Hospital. The main principles on which the open ether method depends are gradual induction with weak vapour of increasing strength, and maintenance by a constantly supplied, uniform ether atmosphere, air being freely admitted throughout. For infants and for very feeble patients ether is dropped on the mask in the same way that is used with chloroform, but more freely, and the mask is not closely applied to the face. Gradualness is achieved by starting with few drops and the mask a few inches off the face. The drops are increased in frequency and the mask lowered till it is only just off the face. A little coughing or holding of the breath is not uncommon. The latter is soon remedied by rubbing the face and lips. The former passes off if the rate of dropping is slowed. Such free air supply as is here indicated will not permit anæsthesia with ordinary individuals. With them the manner of using open ether involves arrangements to secure the passing of the respirations entirely through the material which carries the ether. The mask consists of a metal frame covered with two layers of domette or several

FIG. 7.—Skinner's mask.

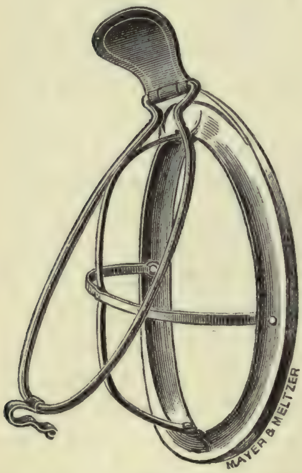


FIG. 8.—Schimmelbusch's mask.

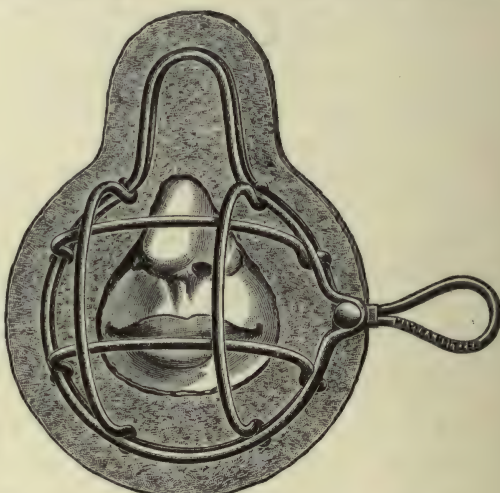


FIG. 9.—A mask for open ether.

[1] *The Railway Surgeon*, Vol. 2, No. 23, p. 529.

layers of fine gauze, or one of lint or of flannel. The nature of the material does not matter so long as it is not thick enough to impede the breathing and so long as it allows the ether to diffuse readily. The frame, too, may be of various patterns. It must be large enough to cover the mouth and nose easily, not heavy, and easily held and easily sterilized. The ordinary Skinner and Schimmelbusch frames covered with two layers of domette I find perfectly satisfactory (Figs. 7 and 8). Ferguson's mask [1] is rather complicated, and does not, according to my own experience, allow a sufficiently concentrated vapour. Fig. 9 shows an American pattern which is very convenient. In order to ensure that the respirations pass through the mask and not at all around it a pad is laid on the face and the rim of the mask rests on this pad. The pad may easily be provided by a few turns of a roll of gauze, by gamgee tissue with a hole torn out for mouth and nose, or a hand-towel may be so arranged as to form a thin, oval cushion on which to rest the mask. This being in position, the patient is asked to breathe in and out of the mouth, and ether is allowed to drop on the mask. The drops must fall quite slowly at first so that no irritation of the larynx is brought about, which would lead to coughing or holding of the breath. Some swallowing generally takes place during the first few minutes. Gradually the whole surface of the mask is wetted with ether, about four minutes being taken to reach this point. Then the dropping is kept going perfectly continuously, and anæsthesia is obtained in about eight minutes on the average. Naturally the time taken and the amount of ether needed, both for induction and for maintenance of anæsthesia, vary with the different kinds of patient. With the difficult kinds, the plethoric, alcoholic, very muscular and excitable individuals, it may be barely possible to provide a strong enough vapour to secure the necessary narcosis for abdominal or rectal operations, for instance. Reinforcing of the mask may then be practised, converting the method almost into a semi-open one. This is most easily done by turning the free part of the towel, which has been laid on the face as a pad, over the mask. Some anæsthetists cover the mask with mackintosh except for a small area at the top on which the ether is dropped. In this way enough re-breathing is secured to allow even the most resistant subjects to be completely subdued. It is essential that breathing should be perfectly free throughout, and with most individuals this means that it must be oral. Any straining nasal breathing or any obstructed mouth breathing must be corrected either by the use of a small prop and manipulation of the lower jaw, or, if that does not succeed, by the insertion of an air-way

[1] *Lancet*, Feb. 12, 1921, p. 336.

into the mouth. Some anæsthetists prefer to keep the air-way free, when there is difficulty, by holding the tongue forward with a tongue-clip. This is a more laborious method and sometimes leaves the patient afterwards with an aching sensation about the root of the tongue. The actual percentage vapour of ether inhaled when it is given as above described is about 10 per cent.[1] This strength is, of course, greatly increased when the mask is covered over with a towel. Hewitt and Legge Symes estimated that gauze yielded a higher percentage than lint or flannel, the percentage rising roughly according to the number of layers, and

FIG. 10.

FIG. 11.

that the percentage ranged between 5 and 15, according to the extent of the douching and the nature of the fabric. One of the most important points in the practice of the open method is absolute continuity of dropping of the ether. There must not be occasional free douches of the mask. The ether must drop on the mask with continuous uniformity, so that the vapour supplied is kept equable. With an 8-ounce ordinary coarse blue glass bottle fitted with Bellamy Gardner's stopper (Fig. 10) it is generally easy to arrange the position of one's arm and hand so that a continuous drip leaves the stopper and falls on the mask, movement being only occasionally needed as the bottle empties. Jackson's ether bottle is also very convenient (Fig. 11). Another useful ether dropper[2] is the simple metal can introduced by

[1] *Proceedings British Association,* 1911 (Anæsthetics Committee).
[2] *Brit. Med. Journ.,* Mar. 1, 1913.

McCardie (Fig. 12). The "etherometer" (Fig. 12A) is a useful contrivance for supplying ether by drops in an automatic manner. When pressure within the bottle has been worked up by the hand pump, the anæsthetist has merely to regulate the rate of

FIG. 12.

flow of the drops by turning the screw-top of the bottle. Large amounts of ether are expended in the course of long operations performed under open ether. The amounts vary, of course, with the nature of the patient and his respiration, the heat of the room,

FIG. 12A.

the character of the operation, and the extent to which the mask is exposed. For an adult man 8 to 10 ounces may be taken as an average expenditure. For the truly difficult subject open ether may not suffice. It may not be possible, that is to say, to obtain anæsthesia in an individual of that kind within reasonable time using merely open ether, although this may be enough to maintain

anæsthesia if it is once induced by C.E. mixture or chloroform. On one occasion at the end of twenty minutes, during which time 4½ ounces of ether were consumed in the attempt to induce narcosis, excitement with a slightly diminished conjunctival reflex were the only indications of approaching anæsthesia. The patient was a London horse-cabman, a cheery, red-faced, thick-set beer-drinker of forty-four. Open ether was changed for C.E. mixture and anæsthesia induced in a few minutes. Hewitt was watching this case, and expressed the opinion that at least forty minutes of open ether would have been needed to get anæsthesia. It is interesting that difficulties of this kind seem rare in America, where open ether appears always to suffice. American anæsthetists in this country and in France during the Great War, however, were surprised at the difficulties which they met in procuring anæsthesia with open ether. They were at first inclined to suspect that the ether was less potent than their own. Tests, however, did not justify this opinion, and the general belief came to be that the causes of the different behaviour to open ether in America and in Great Britain were probably racial and climatic. It happened that the author had frequent opportunities of using ether sent over from America to one English military hospital. He was unable to detect any noticeable difference in the behaviour of English patients whether they were subjected to this or to the native brands of ether. The amount of ether vapour present in the air of the operating room during a long open administration becomes great. In its early days one London surgeon remarked that he was made sick by this method whether the patient was or not. Experience, however, enables the anæsthetist to curtail very considerably the amounts used, and the smell of the theatre is rarely a serious inconvenience. The *muscular relaxation* that can be obtained by open ether is extreme, but much time may be needed. Thus, when the method is used for abdominal operations the anæsthetist is well advised to start his administration at least a quarter of an hour before the surgeon wishes to begin. If the patient is a difficult subject, even longer is desirable. If the operation is allowed to begin before a very deep narcosis has been obtained it may be almost impossible with open ether to quell the reflex tightening of the abdominal wall. Open ether is often of great value in the case of patients whose condition is desperate. For many of these subjects it provides the safest form of anæsthesia possible. An excellent example of this class of case is recounted by Hewitt.[1] The anæsthetist using open ether must always be on his guard against letting its obvious safety at the time mislead him into such a free use of the drug that the patient's

[1] Hewitt, *loc. cit.*, p. 337.

condition is jeopardized afterwards. Moist respiratory sounds, a pale and sweating skin, shallow or wheezing breathing, widely dilated pupils, and eyes rolled back behind partly open lids are all warning signs that too much ether has been inhaled. Moist sounds in the breathing may arise without an overdose. They may simply show too profuse a secretion of mucus with some inhalation thereof. Ether should then be abandoned in favour of chloroform. This necessity does not often arise when appropriate doses of atropine have been used before the inhalation. Hypodermic injections of *atropine beforehand* are to be regarded as an essential feature of open ether administration. Some anæsthetists always combine these with morphia or with scopolamine. Used as a routine, however, often in hospital practice for patients whom

FIG. 13.

the anæsthetist has not seen, the atropine is better given alone. The doses should be $\frac{1}{100}$ grain for adults, and $\frac{1}{120}$ grain for children not younger than about ten. Smaller children may have $\frac{1}{150}$ of a grain. The injection is given an hour before the operation. The addition of morphia and of scopolamine is an advantage for the use of open ether on alcoholics and other difficult subjects, so that when these are seen beforehand by the anæsthetist he will generally order the combined injection. Atropine alone does not notably increase the patient's susceptibility to narcosis, but its value lies in the freedom it ensures from excessive mucous and salivary secretion.

The open method can be employed **in the nose during operations within the mouth,** removal of the tongue, malignant growths of the tonsil, and the like. It obviates the necessity for a laryngotomy and may be regarded as an alternative

to intra-tracheal insufflation in suitable cases. The apparatus necessary is that devised by Crile (Fig. 13). It consists of a large glass funnel, the wide end of which is covered with a layer of thin flannel. The narrow end fits into a wide rubber tube, which, with the interruption of a glass trap, to prevent liquid ether entering the nasal tubes, passes on to a V-piece which connects the wide tube with two nasal tubes. These are of a size to pass through the nares, fitting them pretty closely. It is in the passage of these tubes in the presence of a deflected septum or other nasal obstruction that the method is sometimes accompanied by difficulty. The patient is first made completely anæsthetic by C.E. mixture or open ether given in the ordinary way. Then the pharynx, epiglottis, and larynx are brushed with a 2 per cent. solution of cocaine. Then the nasal tubes are pushed into the nose until their ends are opposite to the epiglottis. A finger may be inserted

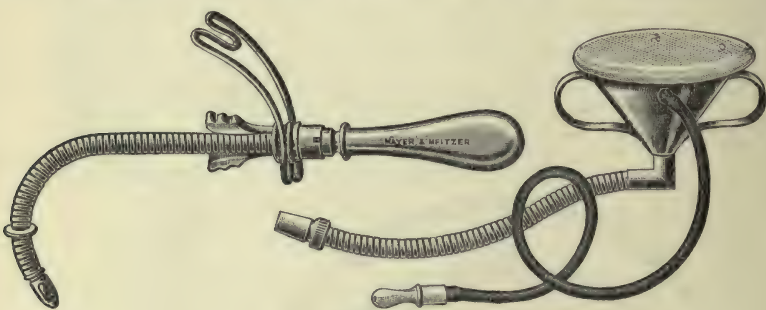


FIG. 14.

into the back of the mouth to make sure that the ends of the tubes are in the desired position. The tongue is then pulled forward and the pharynx carefully packed around the tubes with sterile gauze. Ether is then supplied by continuous dropping on the flannel over the funnel. Sington [1] describes a simple apparatus for the administration of open ether during throat operations. It consists mainly of a Woulff's bottle, a foot-pump, and a coil of malleable metal placed in a vessel containing hot water. This is joined up by a length of rubber tubing to a metal tube which is placed within the mouth. Warm ether vapour is freely provided when the foot-pump is worked. Pharyngeal anæsthesia can also be carried out by the use of Kühn's tube (Fig. 14), which is passed through the mouth to the larynx. The end projecting from the mouth is joined up with a funnel for ether dropping, as with Crile's tubes. *Oxygen* may be given with ether by the open method. This combination is only needed, or indeed effective, with patients who are reduced to the lowest degree of feebleness. In an

[1] *Lancet*, July 2, 1921, p. 24.

operation for double empyema, for example, on a patient with pericarditis, it allowed the procedure to be safely carried through when it was doubtful whether any other form of general anæsthesia could have done so. Palermo [1] recommends the use of ether and oxygen in cerebral and spinal surgery. It appears, however, that he is satisfied with a narcosis so light that it would be unacceptable to many operators. From the point of view of avoiding the serious shock which accompanies some of these operations there would be much to be said, however, in favour of ether and oxygen. The apparatus required is simple. Oxygen may be bubbled straight from the cylinder through a bottle containing ether from which a second tube leads to a face-mask, or else the oxygen may be led from the cylinder to a bottle containing hot water, bubbled through this and along a tube to a Skinner's mask on which ether is dropped. Shipway's warm vapour apparatus offers a very convenient means of giving oxygen with ether when desired. All that is needed is to fit a rubber tube from an oxygen cylinder on to the apparatus in place of the hand-bellows. Turning on the oxygen, with the dial marking E, sends a continuous stream of warmed oxygen and ether to the exit tube.

Semi-open inhalers, of which Rendle's and Allis's are familiar examples, do not offer any advantage over the open method on the one hand and the closed on the other. It is not easy to graduate the vapour supplied by these inhalers with much delicacy. For this reason induction of anæsthesia, if carried out with a semi-open inhaler, is a less smooth process than it commonly is when an open or a closed method is properly employed. The vapour supplied can, of course, reach a higher degree of concentration than with the open method. What the actual percentage strength is when a Rendle or an Allis mask is freely douched with ether there is no evidence to show, but probably the vapour inside the mask can be made at least as strong as 20 per cent. Certainly a very effective vapour can be supplied, and for this reason these and similar inhalers, such as that devised by Harold Low, are sometimes preferred for the maintenance of ether narcosis in resistant subjects. Where ether is freely supplied to a Rendle's mask there is a great tendency for freezing to take place on the sponge which in this inhaler holds the ether. In Allis's inhaler the ether is dropped or poured upon a flannel bandage stretched across a metal frame surrounded by leather. These semi-open inhalers are less easily cleansed than simple open masks, and the sponges and flannel used in them need replacing after every administration. The procedure in using a semi-open inhaler is simple. Half an ounce of ether is poured upon the sponge or

[1] *Medical Record*, Feb. 7, 1920, p. 231.

receiving surface of the inhaler. The instrument is then held a few inches from the patient's face and gradually lowered. After a couple of minutes or so it rests on the face. From time to time it is lifted off to have fresh ether added. Free oral breathing is to be maintained, a prop being used if necessary, and the patient's face is kept turned well to one side. The amounts of ether expended in the course of a long operation are considerably less than when the open method is used, but greater than with the use of a Clover's inhaler.

In **vapour methods** of administration the patient's respiration

FIG. 15.

plays no part in vaporising the ether, which is supplied as a vapour by a current of air driven through or over the liquid. Shipway's apparatus (Fig. 15) supplies the vapour warmed by its passage through a metal tube contained in a thermos flask. The advantages of supplying anæsthetic vapours warm have been discussed (p. 95). It is noteworthy that Lawson Tait in 1883 published an account of an apparatus for administering ether vapour at blood heat. Apart from the warmth, Shipway's apparatus affords a very convenient method of maintaining an equable ether anæsthesia in long cases. It is easy by rhythmical, equal compressions of the hand-bellows to keep up a constant supply of a vapour of uniform strength. Uniformity is more easily achieved, in fact, than by the drop method, and also with much less

inconvenience to the administrator. There is also far greater economy of ether. For resistant subjects the vapour supplied is not always sufficiently powerful. The apparatus has not the same advantages for inducing anæsthesia that it has for maintaining narcosis. At first the draught with which the vapour is supplied is not so agreeable to most patients as is simple inhalation of the vapour from drops on a mask. Induction may, then, be preferably carried out by the drop method, using the mask attached to Shipway's apparatus, and maintenance continued by use of the hand-bellows. Eight ounces of ether are to be poured into the ether bottle and warm water put into the metal pocket in which the bottle stands. The following description is mostly taken from Shipway's article [1] :—

The warming chamber, which is a thermos flask, is filled with water at about 145° F. In the cork of the ether bottle (E, Fig. 15) are (1) an efferent tube, (2) a filling funnel, and (3) a regulating tap (T), the long limb of which is plunged into the ether ; perforations at the end of this limb break up the air current and prevent splashing of the ether. To the proximal of the two short limbs of T is attached the hand-bellows. The distal is connected by rubber tubing with the efferent tube of C. The efferent tubes of E and C are connected by tubing to the branches on the efferent limb of V, which is a metal V-piece immersed in the warm water of W. The delivery tube of V carries 30 inches of rubber tubing. By regulating the lever of T air can be pumped through E, through C, or in varying proportions through E and C at the same time, so that the vapour of ether, of chloroform, or of mixture of the two can be given. The hand-bellows is of a size that fills the hand and makes continuous pumping not tiring. The anæsthetist has two means of altering the strength of vapour supplied : one is regulation by the tap (T), the other by varying the vigour with which he squeezes the hand-bellows. When used for ether only C and its jacket are detached, the distal branch of T being then connected with the free branch of V. The vapour from the delivery tube of V must not pass directly into metal, which rapidly cools it. It can be delivered under any ordinary open mask. The following figures indicate the temperature of the vapour supplied according to the temperature of the water in the warming chamber and in the water jackets surrounding the ether and chloroform bottles :—

Room Temperature.	Water in Jackets.	Water in Flask.	Temperature of Ether Vapour at Exit of Efferent Tubing.
78·5° F.	71° F.	142° F.	94° F.
68° F.	74° F.	150° F.	93° F.
73° F.	55° F.	152° F.	90° F.

For operations of ordinary severity on patients in good condition the vapour supplied should be about 90° F. It may be

[1] *Lancet*, Jan. 8, 1916.

warmer with advantage when supplied to those who are in a state of shock or undergoing prolonged and trying operations. It has been maintained [1] that with ordinary drop open-ether methods the vapour which enters the mouth does so at very nearly body temperature. It is warmed to about 32° C. in the enclosed space in front of the mouth, which forms a natural warming chamber. Further heat is gained when the vapour enters the pharynx, and the warming process is completed before the vapour enters the respiratory tract proper. Nevertheless, since the warming is all supplied by the body heat, there must be a certain, though not a great, conservation of this when the vapour is supplied warm. Even this little gain of body heat is valuable when the patient is very feeble or severely shocked. Those who advocate warmed vapours also claim that the toxicity of anæsthetics is thereby decreased, and support their claim by experimental evidence. On the other hand, it is asserted that anæsthetic vapours always reach the alveoli of the lung at body temperature, however the anæsthetic is administered, and cannot go into solution in the blood without instantly attaining the temperature of the body.

L. J. Picton [2] has attempted to supply a warmed vapour by a modification of the drop method. He shows that during expiration, with an ordinary mask, the vapour is warmed to the required point (about blood heat), but during inspiration it is much cooler. His apparatus is designed to get rid of this low inspiration temperature.

It consists essentially of a metal chimney built upon an ordinary mask. The open top of the chimney, 4 inches in diameter, is closed with a drum of gauze of two or three thicknesses. This is kept just saturated with ether. The chimney narrows in the middle to a waist 2½ inches in diameter. Here is another drum of gauze of one thickness clamped between the upper and lower halves of the chimney. A third layer of gauze, also single, forms a dome in the lowest part of the chimney. Between the top drum and the waist the vapour is cold, as is indicated by condensation of moisture on the outside of the chimney. The lower half of the chimney is free from condensation and comfortably warm to handle, for the vapour within it is automatically warmed by admixture with expired air.

A simple and effective apparatus for the delivery of warm ether is described by Messrs. S. N. Wilson and K. B. Pinson.[3] Their apparatus supplies a stronger vapour than other warm vapour instruments and is self-delivering, no bellows or pump being needed.

It consists of a strong steel vessel, capable of holding half a pint of ether, tested to withstand a pressure of 250 lbs. per square inch. The

[1] *Amer. Journal Surgery* (Supplement), 1917, Vol. 31, p. 46.
[2] *Brit. Med. Journal*, July 17, 1920, p. 69.
[3] *Lancet*, Feb. 12, 1921, p. 336.

supply of vapour is regulated by a needle-valve. This has a graduated ebonite top and a pointer indicating the extent to which the valve is opened. The delivery pipe of the valve is connected by rubber tubing to an ordinary open ether mask. The temperature beneath the mask is between 90° and 98° F.

Closed Methods

Although regarded as already obsolete by some authorities, the closed method of giving ether has a distinct sphere of usefulness. This has been indicated (p. 106), but we may add that for the practitioner who only occasionally administers anæsthetics it furnishes, if he has once acquired skill with it, a highly efficient and safe measure. The apparatus that he must carry is not extensive, and he is in possession of a means of giving ether with which he can manage any ordinary individual, however strong a dose is required. In hospital practice it is time-saving and admirably adapted to short operations requiring deep narcosis, for example the common operations for hæmorrhoids and fissure and operations on the fingers and toes. The large number of inhalers for giving ether by a closed method are all more or less varieties of Clover's portable regulating ether inhaler or of Ormsby's inhaler. These two alone therefore demand detailed description, and if the way to use them is clearly shown the reader will easily adapt the information to other inhalers of similar type. Clover first introduced his regulating inhaler in 1877, before which time there appears to have been no general use of a closed method nor any serviceable inhaler, although for several years before ether had been administered from a bladder or bag.[1] The great virtue of the Clover inhaler is the extreme gradualness with which it allows the strength of the ether vapour inhaled to be increased. The mechanical ingenuity of Clover was nowhere better shown than in the contrivance by which he rendered this gradual assumption of ether vapour possible.

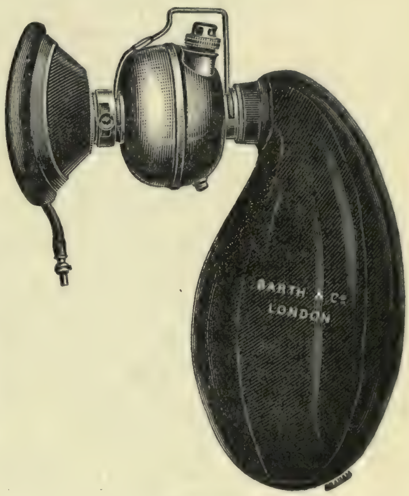


Fig. 16.

[1] Hewitt, *loc. cit.*, p. 344.

This contrivance consists of a shaft traversing the ether chamber and a tube fitting into the shaft. Half-way along the shaft are four large openings allowing of communication between the interior of the shaft and the ether reservoir. These openings are large and almost completely divide the shaft. A half-diaphragm runs diagonally from the wall of the shaft, closing one half of its calibre at the level of the openings. The tube which passes through the lower end of the shaft from the face-piece has a whistle-shaped end which fits against this half-diaphragm. On this tube when it is fixed into the face-piece the ether reservoir revolves. The tube carries an indicator, and the reservoir is marked with figures which pass this indicator as the reservoir is turned. The position of these figures indicates the extent to which an inspiration traverses the ether chamber before it reaches the face-piece. When the indicator is at " o " a breath drawn through the inhaler goes straight down the shaft without passing over any ether. The openings from the shaft to the ether are cut off by the diaphragm and the whistle-shaped end of the tube. As the reservoir is turned a larger and larger proportion of the inspiration is forced by the internal arrangement which has been described to pass over the ether before it reaches the patient. That is to say, a smaller and smaller proportion of the air current is drawn straight down the shaft and a larger and larger portion has to take the indirect route over the ether. When the mark " F " is reached the whole current is deflected over the ether before it reaches the mouth. Outside the ether chamber is a water chamber which prevents the apparatus becoming too cold . . .

The original pattern of this instrument has been improved upon in Hewitt's modification [1] (Fig. 16). The internal calibre is much larger. The central tube rotates within the fixed reservoir, and this central tube is divided into two portions, which, however, rotate as one because of the indicating handle which fits into each. It is important if the instrument is dismantled for cleaning or greasing that these two halves of the central tube should be correctly replaced. Otherwise it is possible to fit up the apparatus so that when the indicator is at " o " the effect is that which should follow when it marks " F," and *vice versâ*. Hospital porters have not infrequently made this mistake, with uncomfortable consequences for the patient on whom the apparatus was next employed. To be sure that the apparatus is correctly put together, turn the indicator to " o," hold up the instrument, and look through the face-piece. There should be a clear, unobstructed view through the central tube. The face-piece in Hewitt's apparatus is screwed into the ether reservoir so that these two parts cannot become accidentally separated, which happened sometimes to the older instrument. The ether reservoir can be adjusted to the face-piece so that ether can be inserted through the filling tube without removing the face-piece, whatever the position of the patient's head. The filling tube is fitted with a stopper that has a glass window. This enables one by tilting the instrument to see that the ether is not used up.

[1] Hewitt, *loc. cit.*, p. 349.

The best results can be got with a Clover's inhaler only after much practice. This is because the anæsthetist must acquire a sense of touch, almost like a rider's "hands" on his horse's mouth, which enables him to bring exactly the right amount of pressure to bear upon the face. Too heavy a hand will often press back the chin and cause obstructed breathing; too light a touch will allow air leakage. Practice only can give the correct appreciation of what the face-piece is doing to the patient, and practice only can teach exactly the rate at which the ether strength must be increased with different patients. The administration of ether by Hewitt's modified Clover (Fig. 16) is carried out as follows. First warm the inhaler by turning the indicator to "¼" and pouring in an ounce or two of warm water and emptying it out again. Now pour in an ounce and a half of ether, replace the stopper, turn the indicator to "0" and, pressing the face-piece to your own face, blow hard through the inhaler, in order to get rid of all ether vapour lingering in the central shaft since the insertion of the liquid. It is important that when applied to the patient's face the inhaler should carry no smell of ether at all. A drop of essential oil of orange inside the face-piece gives a pleasant odour, obliterating any suggestion of ether or of rubber and so helping the patient to breathe freely from the first. Many patients are highly susceptible to the smell of ether. The filling of the inhaler should not be carried out in their immediate vicinity. The patient being now ready and in position (p. 103), and the face-piece screwed on to the reservoir so that the narrow part of the face-piece corresponds with the bridge of the patient's nose, the inhaler is carefully adapted to the face. The anæsthetist grasps the face-piece firmly in his left hand so that he controls the weight of the apparatus and has an accurate feel of the pressure he is exerting. The reservoir part of the apparatus may rest against the fingers of the right hand. The patient breathing air freely through the inhaler, the bag is now taken by the right hand and fitted on the top of the inhaler during an expiration. For the first breath or two after the bag is put on the face-piece is made to rise from the chin during inspiration and descend again with expiration. In this way the bag is well distended. Then with the right hand the anæsthetist pushes the indicator away from "0." This he does very slowly. At least a minute should be taken in travelling from "0" to the next figure. A little advance is made with each inspiration, and any cough or holding of the breath leads to a halt, or if it continues, to a pushing back of the indicator. In this way the indicator is very gradually advanced, and when the half-way mark is reached a breath of air is admitted by raising the face-piece with inspiration and replacing it to catch

the following expiration. From this point the ether strength can be increased more rapidly, and any coughing is to be met, not by retreating, but by advancing the indicator. After about four minutes, as a rule, the indicator reaches its limit (F) and the patient is stertorous and relaxed. It is absolutely essential for quiet induction of narcosis that the indicator should be pushed on very slowly at first. If the journey from "o" to "F" takes four minutes, three of these should be used in reaching the half-way mark ("2"). When that point is reached the sensibility of the larynx is so diminished and consciousness so faint, if not altogether gone, that a strong vapour can be pressed upon the patient without causing him inconvenience. It will be observed that breathing in and out of the bag takes place throughout except for the occasional breaths of air. There is therefore very considerable air-limitation, and this naturally causes some cyanosis. This is to be permitted until narcosis is secured. If the anæsthetist aims at keeping the face entirely free from duskiness during the induction he will often meet with excitement. At the same time he does not, of course, permit the cyanosis to be extreme. The extent to which he allows it varies greatly according to the type of subject. The easy subject, particularly if at all anæmic, can be allowed breaths of air so frequently that he is never cyanosed at all. The robust, high-coloured individual, on the contrary, must be far more strictly limited. Even if the face is much congested, especially if the patient is alcoholic, air must be only sparingly admitted till the breathing is stertorous and the muscles relaxed. This may not be till after a minute or so of much muscular spasm and rigidity in difficult subjects. The vast majority of healthy adults display little or no excitement or spasm during an induction when properly carried out. When anæsthesia is reached there are stertorous breathing, insensitive conjunctiva, flushed or dusky face and relaxed limbs. The pupil is moderately dilated, and the corneal reflex soon goes if the indicator is kept at "F." With strong or difficult subjects it should be kept there till the skin incision has been made. Then it is pushed back to "2," and for easy subjects it may be returned to this point when anæsthesia is obtained and before the operation begins. The remarks that have been made with regard to duskiness of the face during induction of anæsthesia do not apply to the subsequent period of maintenance. When once anæsthesia has been gained cyanosis is not to be permitted. Air is to be admitted often enough to keep the patient rosy, but not dusky. The frequency with which breaths of air are needed for this varies, of course, according to the type of patient. The pale, thin woman may need alternate breaths of air and ether. Generally a breath

of air about every fourth respiration keeps the desired colour. The longer the operation the more freely is air supplied and the lower is the figure at which the indicator may be kept. The concentration of ether vapour in the bag when the indicator is at "F" must be very high. No accurate observations on the point have been made so far as I am aware, but, judging from the facts known of vapour strengths under an open mask, we may reckon that the vapour in the bag is not under 20 per cent., and probably rises a good deal higher. The blood pressure is raised during short administrations of closed ether, and shock is notably slow to appear even with severe surgical trauma.

FIG. 17.

Ormsby's inhaler is a simpler instrument than Clover's. It has no facility for graduating the dosage delicately, and consequently is better suited to maintaining anæsthesia than to inducing it. For the former purpose it is a most efficient instrument, particularly well suited to patients who require large amounts of anæsthetic. The best form of the inhaler is that devised by Carter Braine (Fig. 17).

This consists of a metal face-piece, the rim of which may be guarded by a rubber pad, and a metal cage fitted on to the top of the face-piece by a bayonet catch and containing a sponge. Over the cage is fitted the mouth of a 12-inch wide rubber bag. The face-piece has a slot by means of which breaths of air can be admitted without raising the apparatus from the face. Before use a coarse sponge about large enough to stay in the cage when this is held upside down is wrung out in warm water and placed in the cage.

The air-slot being open, ½ ounce of ether is poured on to the sponge and the inhaler is held near, but not on, the patient's face. His breathing being uninterrupted by coughing or swallowing or holding of the breath, the instrument is allowed to approach still nearer to the face and the air-slot is gradually closed. After a couple of minutes the face-piece rests on the face and the air-slot is shut. From now till anæsthesia is obtained the face-piece is kept firmly pressed upon the face. Some excitement is more

likely to occur than with the Clover, but there must not be too great a readiness to give breaths of air until unconsciousness is complete. When anæsthesia is established air admission is practised according to the need of the particular patient, just as previously described. Half an ounce of ether is poured upon the sponge from time to time, as is found necessary. If ether is used freely, snow may form on the sponge, and an alternative one in warm water should be ready to hand. Some cyanosis may be allowed during induction, and is necessary with difficult subjects if long excitement is to be avoided. When anæsthesia is established no further duskiness of the face should continue.

A simple apparatus which gives good results and is much in vogue in some European countries is that of Rovsing. This consists of a thick rubber face-piece with a hard rubber sleeve and a sheet of gaudafil tissue about 75 cm. square. This is gathered round in the form of a bag with a capacity of 3 to 4 litres, and is tied with tape over the rubber sleeve. Ether is poured through the sleeve into the bottom of the bag. The amount used is 60 to 75 c.c. per hour, re-breathing being employed and the ether warmed by grasping the dependent bag.

Intra-tracheal insufflation of ether is a method of the greatest value in all operations which involve the chance of blood entering the air passages, in extensive operations within the thorax, and in the long face and jaw operations of war surgery. The method renders the entry of blood into the air passages practically impossible owing to the return current of air which is blown out around the catheter. It enables the anæsthetist to be away from the surgeon's area in operations about the face, and in intra-thoracic operations it supplies a positive lung pressure, and thus renders the surgeon independent of anxiety due to the effect on the lungs of opening the chest. It eliminates also all local respiratory obstruction, which is so apt to arise from spasm or congestion of the tongue, pharynx, and upper air passages. The apparatus required is of necessity rather complicated, and much practice is needed before the catheter can be passed into the trachea with ease and certainty. Since all the dead space between the bifurcation of the trachea and the mouth is eliminated by this method and the ether vapour is supplied practically directly into the lungs, an economy of ether is effected in addition to the advantage of cutting out much of the mucous and salivary secretion of the mouth and upper air passages. Moreover, there is no swallowing of ether-laden mucus and saliva, and consequently vomiting afterwards is diminished. The method gives the anæsthetist very accurate control of the vapour which he is using. It supplies an admirable form of artificial respiration, since even

if respiratory movements cease the respiratory exchange of gases can be kept up for hours by insufflating air. This was shown experimentally by Meltzer and Auer. These observers [1] found that "if they passed a tube through the larynx of a dog almost to the bifurcation and blew air through this tube in a continuous stream, the animal could be kept alive for many hours even after all voluntary respiratory movements had been abolished by curare." It is to the work of Meltzer and Auer and to the adaptation of it by Elsberg that we are chiefly indebted for this method of anæsthesia. In Great Britain R. E. Kelly and Shipway have designed good apparatus following on the lines of the American pioneers. Meltzer and Auer used for their experiments a simple form of apparatus which has not all the safeguards needed in practice. They established, however, the principles of intra-tracheal insufflation of anæsthetics. Meltzer's words may be quoted: "The essentials of the method consist in the introduction deep into the trachea of a flexible, elastic tube, the diameter of which has to be much smaller than the lumen of the trachea, and the driving through this tube of a nearly continuous stream of air which returns through the space between the tube and the walls of the trachea. . . . A well-arranged intra-tracheal insufflation is fully capable of relieving and replacing the normal respiratory mechanism. The practically continuous recurrent air stream prevents the invasion of indifferent or infectious foreign matter from the pharynx into the trachea. The usefulness of the method is at least threefold. (1) It is capable of keeping up an efficient respiration in cases in which the normal mechanism of external respiration fails. (2) It overcomes efficiently and conveniently the difficulties presented by double pneumo thorax. (3) It offers a safe and reliable method for anæsthesia, especially for the administration of ether." The essentials required of any apparatus for insufflating the human subject with ether are: (1) A source of air—hand-pump, foot-bellows, or electric motor. (2) Tubes to the ether reservoir and from it. A mercury manometer must be included in the circuit in order that the pressure at which the vapour is delivered into the trachea may be known. (3) A regulator which will permit an automatic blow-off if the pressure becomes too great. (4) A warm water tank to moisten and warm the stream of air and ether before it reaches the lungs. (5) A catheter of suitable size and material. In practice another essential is a direct laryngoscope through which the catheter is passed. In many adults the epiglottis cannot be reached by the fingers. Various instruments have been constructed to facilitate the passage of the catheter when it could not be made by touch.

[1] Gwathmey's "Anæsthesia," p. 417 (Elsberg).

The surest plan, however, is to use the direct laryngoscope. Some anæsthetists apply cocaine to the epiglottis and posterior wall of the pharynx before passing the laryngoscope. As, however, full anæsthesia should be brought about by ordinary inhalation before the instrument is passed, this is unnecessary. Meltzer showed that in an animal the catheter, if carefully introduced, may be left in the trachea for hours without causing any damage to larynx or trachea. The same appears to be true of the

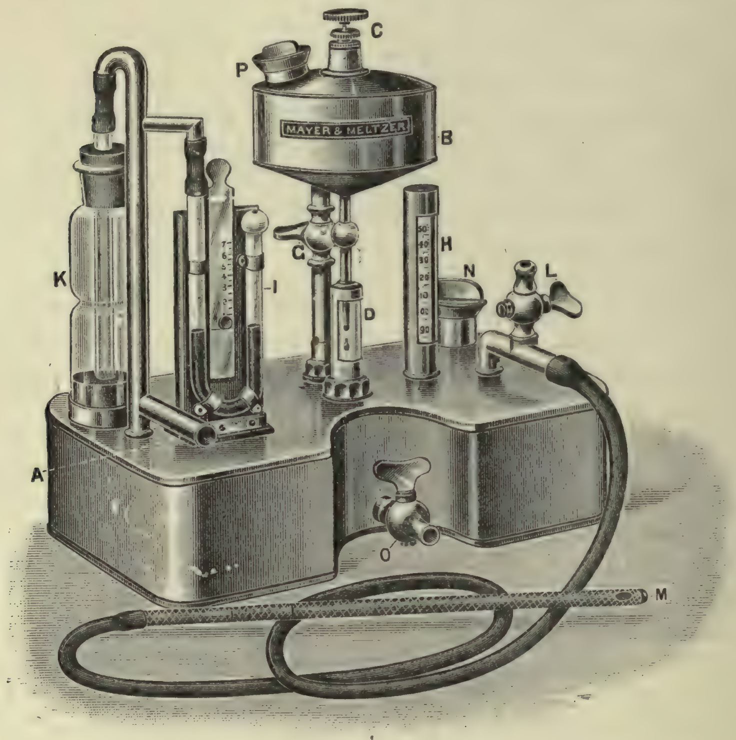


FIG. 18.

human being, for no after-effects in the air passages follow intratracheal insufflation unless there has been difficulty in introducing the catheter leading to the infliction of local damage. Shipway's apparatus (Fig. 18), which is similar to Kelly's, contains all the necessary features, and is not inconveniently large or heavy. It weighs $5\frac{1}{2}$ lbs., measuring $8\frac{1}{2} \times 4\frac{1}{2} \times 12$ inches. The following is from his paper introducing the machine [1] :—

The idea underlying the apparatus is that ether drips from a container into a central chamber, through which passes the air current from the motor or foot-bellows, and is there vaporized, partly by this means and partly

[1] *Lancet*, Aug. 5, 1916.

by the heat imparted by an encircling hot-water jacket. The tap C regulates the flow of ether, which can be delivered in drops or in a continuous

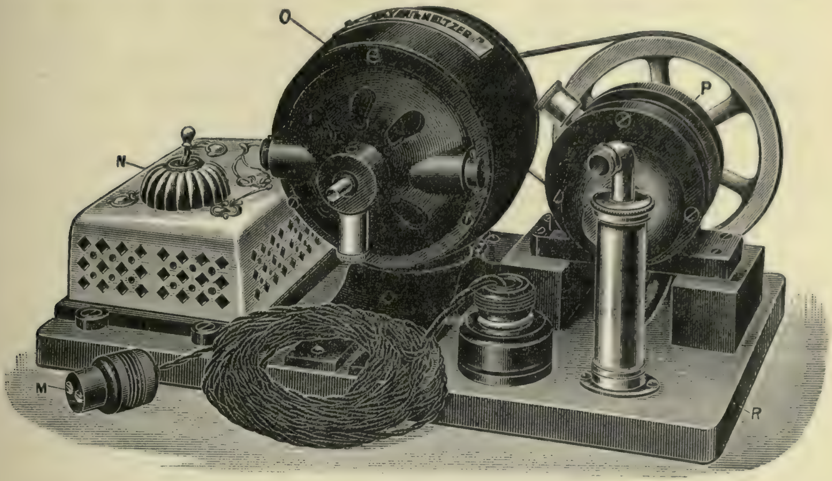


FIG. 18A.

stream. The tube G, connecting the ether container and the vaporizing chamber, equalises the pressure on the upper and lower surfaces of the ether, and regular dropping is ensured. During anæsthesia the tap of the equalising tube must be kept open, but if the container needs refilling during an administration this tap must be first closed before the bung of the filling funnel is removed, and kept closed until this has been replaced. The thermometer should register 110° to 120° F., according to the temperature of the room and the nature of the operation. The apparatus is worked either by the rotary electric pump (Fig. 18A) or by foot-bellows.

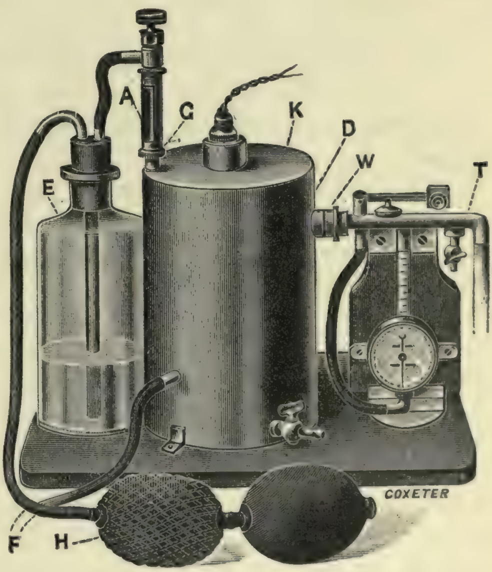


FIG. 18B.

Boyle's [1] apparatus is worked solely by the foot-pump. It has no safety valve. Magill's apparatus (Fig. 18B) has the advantages of simplicity and portability. Elsberg [2] relates

[1] *Lancet*, Nov. 30, 1912.
[2] Gwathmey, *loc. cit.*, p. 430.

instructive cases showing the danger of faulty apparatus. In one instance liquid ether was blown into the lungs, one of the tubes leading to the ether reservoir being under the surface of the ether. In other instances the pressure was too high, injury to lung tissue and subcutaneous emphysema resulting. In another case a soft rubber tube was passed down the trachea and completely filled one of the branches of a bronchus, allowing no air to escape. The size of the catheter is important, and is governed partly by the depth of narcosis required for the particular operation. The larger the catheter used the deeper will be the anæsthesia obtained. The diameter should about equal half the length of the glottis as seen in the laryngoscope. Generally the sizes 22 French for adults and 18 to 21 French for young subjects are suitable. The catheter should be marked to show when it has reached the bifurcation of the trachea, a second mark indicating when it is about 3 cm. above that point. The mark showing the bifurcation is at 26 cm. from the tip for the average male adult, 2 or 3 cm. less for the female. Catheters should be silk-woven and semi-rigid, sterile and dry, and 30 cm. long. Shipway has pointed out that the size of the catheter bears also on the pressure readings of the mercury manometer.[1] With 23 French the readings are generally about 12 to 14 mm. Hg.; with 22 French or 21 French they are higher. The other factors determining the manometer figures are the velocity of the air stream and the resistance of the apparatus. The safety valve should be set to blow off at 20 mm. Hg.

Administration.—The anæsthesia is induced with open ether in the ordinary way and with the usual preliminary injection. If owing to the presence of partial tracheal obstruction there is fear that inhalation anæsthesia may render this complete, the catheter may be passed after cocainization of the larynx and without anæsthesia. When the catheter has been passed through the cocainized larynx anæsthesia is most comfortably induced by a mask held over the end of the catheter. Insufflation for the induction of anæsthesia causes great discomfort because of the reflexes at the bifurcation of the trachea (Elsberg). In ordinary cases full anæsthesia having been obtained by drop bottle and mask there is no need to cocainize the larynx. The neck of the patient is now put on the stretch, the head hanging back over the end of the table, the mouth is opened with a Mason's gag, and the direct laryngoscope pushed in. The epiglottis is pulled forward by the beak of the laryngoscope and the glottis well exposed. When the opening between the cords is clearly recog-

[1] *Brit. Journ. of Surg.*, Vol. 1, pp. 98 *et seq.*

nized the catheter selected is run in through the laryngoscope, made to enter the glottis, and rapidly pushed down the trachea. The laryngoscope is then withdrawn and a band of strapping applied to keep the catheter in place. The patient's head is now brought on to the table and the neck allowed to resume its normal attitude. Spasmodic coughing and holding the breath often follow immediately on the entry of the catheter. These symptoms, just as after the first insertion of a tracheotomy tube, soon subside and are replaced by regular breathing. The sound of the air entering and leaving the catheter shows the anæsthetist that he has intubated the trachea and not the œsophagus. If he remains in any doubt the catheter should be withdrawn and reinserted. It is quite easy to push it down the œsophagus in error for the trachea. When he is certain of the correct position of the catheter this is joined up to the efferent tubing of the apparatus. Another short attack of coughing often marks the beginning of insufflation. Difficulty in getting the catheter to enter the glottis may be got over sometimes by moving the head slightly to one side or the other, or a little forwards or backwards. The greatest difficulty has been met through fixity and deformity of lower jaw and neck and floor of mouth in those suffering from war injuries of these parts. Shipway pointed out that under these circumstances flexing the neck rendered intubation possible when it could not be effected if the usual position of the head was maintained.

During insufflation quiet respiratory movements should go on. The pressure must never be high enough or the concentration of ether strong enough to put an end to the working of the muscles of respiration. For this purpose the tap L may be turned every two or three minutes. This is not usually necessary unless the motor is running too fast. If cyanosis appears it shows that the catheter is too large or else it is not far enough down the trachea. There should be no sound of mucus rattling throughout the insufflation. The patient's face is pink or rosy and his pulse full and regular—blood pressure, that is to say, is well maintained. A light degree of narcosis is to be kept up throughout, for, owing to the perfect regularity of the supply of the anæsthetic and the absence of all respiratory obstruction, inconvenient reflex phenomena do not occur even during a light degree of anæsthesia. At the conclusion of operation the lungs may be insufflated with air or with oxygen. The anæsthetic is thus rapidly got rid of, and return of consciousness is quick and generally unaccompanied by vomiting or nausea.

Intra-tracheal insufflation by the *nasal route* has been found of advantage in operations on the mouth and lips. S. Rowbotham,

who employed the method at the Queen's Hospital for facial and jaw injuries, Sidcup, points out that, the catheter being out of the surgeon's way, his aseptic technique runs less risk of interference. Three manœuvres are required [1] :—

(1) The passing of the catheter through the nose and naso-pharynx.
(2) Catching the catheter in the oro-pharynx by means of a special guiding rod.
(3) Directing the catheter into the trachea.

These movements may be supplemented by the provision of a return nasal air-way, a procedure which is often helpful to the surgeon in that it prevents bubbling of blood in the mouth and directs expired anæsthetic vapours away from him. Rowbotham dilates the nose with graduated tubing. For a full description of the method, which is only rarely required outside these special operations for war injuries, the reader should consult the original paper.[1] An objection to nasal catheterization is that so frequently a partial obstruction of the nose renders its intubation difficult and accompanied by bleeding. Shipway is opposed to the process on the ground that it involves the risk of conveying foreign matter from the nose to the lungs.

The intra-pharyngeal insufflation of warmed ether by the nasal route was previously advocated by Page.[2] He used two indiarubber catheters, passed through the nares into the pharynx behind the tongue and coupled up with the delivery tube of an insufflation apparatus. Page claimed that in this way the patient inhaled the vapour with a minimum of respiratory effort, without the necessity for tracheal intubation.

Administration of Ether per Rectum.—Although not to be recommended as a routine measure, the administration of ether by the rectal route is often useful. In highly nervous subjects it can be employed for gaining narcosis without the patient being aware that an anæsthetic is to be given (p. 268). Similarly it can be of great service with young and frightened children, who may be persuaded into receiving a rectal injection at the hands of a nurse with whom they are familiar when they would oppose violently any inhalation anæsthetic. Again, it is of much help for severe operations on the larynx, the tongue, or upper jaw in difficult subjects. On all these occasions it is to be regarded as a convenient form of inducing anæsthesia and a help in its maintenance rather than as being necessarily the sole means employed. This is because of the uncertain dosage which the method entails.

[1] *Brit. Med. Journal*, Oct. 16, 1920, p. 590.
[2] *Lancet*, July 18, 1914, p. 156.

The drug is not under control in the same way that it is when given by inhalation. The amount judged correct and injected may prove too little when the patient is on the operating table, when it must be supplemented by inhalation ; or it may prove too much, when some must be withdrawn. Moreover, the injection must be made so long—at least half an hour—before the operation time that in hospital practice the actual administration cannot generally be carried out by the anæsthetist himself. Every precaution must be taken to ascertain the condition of the rectum and colon, any disease of either being an absolute contra-indication to rectal injection Previous dysentery, for instance, must be especially inquired for. One patient in the writer's knowledge, who had previously suffered from this disease and did not mention it to his medical attendants, suffered so severe a recrudescence of hæmorrhagic enteritis as the direct result of rectal ether that the attack proved fatal. Diarrhœa and the passage of small amounts of blood by the bowel have been frequently recorded. Abdominal pain sometimes occurs afterwards, but as a general rule recovery takes place with perfect comfort after several hours of sleep. Ward-sisters have often expressed an appreciation of rectal ether because the patients "had such a good night afterwards." This long period of insensibility must be remembered when the operation is one that may lead to oozing of blood into the air passages. Long-delayed return of the laryngeal reflex may lead to fatal inhalation of blood under these circumstances. For this reason, when the method is used before excision of the tongue and similar procedures, the dosage must be strictly limited, and the anæsthetist must not endeavour to secure by his rectal injection anything more than a preliminary anæsthesia. This effect makes it very easy to keep up by inhalation a most satisfactory narcosis without entailing too long a coma after operation.

The principle of the method rests on the recognition of the power of the intestinal mucous membrane to transmit gases. This quality of the intestinal mucosa has been experimentally demonstrated. Paul Bert showed that if the trachea of a kitten be clamped the animal dies of asphyxia in about thirteen minutes, but if the intestine be inflated with air life may be prolonged for twenty-one minutes.[1] Pirogoff as long ago as 1847 put to practical use this knowledge that the intestinal mucous membrane could absorb vapour and pass it on. He vaporized ether by heat and passed the vapour into the rectum. In spite of the satisfaction which Pirogoff and other surgeons of his time found in rectal administration of ether, it appears to have fallen into disuse for some years. In 1884 Mollière, of Lyons, introduced a new

[1] Gwathmey, *loc. cit.*, p. 434.

technique. Buxton [1] has used the method frequently since 1885; his apparatus provides for the generation of ether vapour by heat and its direct conveyance to the intestines without pumping. An intercepter prevents the entrance of liquid ether into the rectum. For a full description of the apparatus the reader is referred to Dudley Buxton's book.[1] The danger of over-distending the bowel is guarded against in Buxton's apparatus by not evaporating the ether too fast. The water surrounding the ether bottle is not allowed to be of more than 120° F. When ether vapour is pumped into the rectum, or when it is allowed to enter the gut under the pressure incident to its generation, there is great danger of damaging the bowel. Aloi,[2] indeed, believes that in dogs the harmful effect of ether on the intestinal mucosa cannot be avoided even by the ether-oil method. Superficial inflammation or dryness of the mucosa, which may crack and bleed, he found experimentally to be inevitable consequences. These changes, however, were but transitory if the narcosis were short or the rectum washed out afterwards. Sutton states [3] that a number of deaths have resulted from this procedure, and in one of them autopsy showed a gangrenous and perforated cæcum with general peritonitis. That too great distension may occur with Buxton's apparatus seems probable, since he advises that the abdomen be palpated occasionally during the administration, and if undue distension is found the supply of ether is to be checked and flatus allowed to escape *per rectum.* Sutton's apparatus [3] provides for giving a vapour of ether with either oxygen or air, makes the transmission of liquid ether impossible, and includes a manometer, which determines the pressure in the intestine of the patient. It also includes an efferent tube system for exhausting the contents of the gut. The most recently devised means of giving ether *per rectum* is that introduced by Gwathmey as "*oil-ether colonic anæsthesia.*" This is based upon experimental work carried out by Gwathmey and Baskerville, and is probably the safest and most convenient method at our disposal for giving ether by the rectum. The details of the experimental work may be studied in Gwathmey's book.[3] Here it is only necessary to state the chief conclusions to which they lead. The words of Gwathmey's book are freely quoted. Oil was chosen as the medium in order to reduce the bulk of mixture necessary, ether being miscible in all proportions in oil. Oil prevents irritation, and its great affinity for ether prevents a too rapid absorption of the latter. When the oil-ether mixture is in the colon, as the ether leaves the

[1] "Anæsthetics," 1920, p. 202.
[2] *Rif. Med.*, Oct. 9, 1920.
[3] Gwathmey, *loc. cit.*, pp. 441, 444.

oil in gaseous form, heat is extracted from surrounding parts. The mixture and the colon are both cooled. This cooling checks evaporation and absorption The difference between the slow absorption from the colon and the rapid elimination from the lungs assists in automatically regulating the anæsthesia. Another element of safety lies in the fact that less ether is absorbed by the colon when it is distended. There is a constant rate of evaporation of the ether from the oil in accordance with physical laws. The ether passes off slowly at body temperature. Although ether boils at 34·6° C., it does not escape violently from an oil-ether mixture at 37° C. Consequently it is claimed by the authors of this method that a constant uniform supply of ether vapour is maintained as efficiently and safely as if the ether was being administered from outside the body. Although the mixture is in the colon, the supply, absorption, and elimination of ether are regulated by the factors above mentioned as securely as they are during ordinary inhalation. The strength of oil-ether mixture determined by experiment was 55 to 75 per cent. of ether, and the amounts of ether used were from 50 to 70 c.c. Gwathmey recommends, when applied to human beings, a 50 to 65 per cent. solution for children and weak anæmic adults, and a 75 per cent. solution for normal adults. This should, he says, be the maximum strength, and not more than 8 ounces of the 75 per cent. mixture should ever be given. The dosage may be reckoned as an ounce of the mixture for every 20 lbs. of body weight. The mixture is allowed to flow in at the rate of an ounce a minute. All that is needed for the *administration* is a tube or catheter of soft rubber, of about ¼ inch diameter, with its eye on one side and a funnel attached to the other end. The patient lies on his left side with knees drawn up. The tube is passed up about 6 inches ; and the mixture, which is allowed to fill the tube before it is inserted, continues to be poured into the funnel at the slow rate of an ounce a minute. Gwathmey recommends that 2 to 4 drachms of paraldehyde with an equal amount of olive oil be given *per rectum* one hour before the larger injection. Half an hour later morphia and atropine are given hypodermically. Preliminary medication in my own experience has been confined to injections of omnopon, scopolamine, and atropine one hour before the operation, preliminary rectal injections being omitted. According to Gwathmey's directions castor oil is given the night before and warm water enemata on the morning of operation until the return is clear. It is important not to use a soap and water enema, for if soap remains behind in the bowel it may emulsify with the ether and neutralize its activity. The washing out of the rectum should be finished at least two hours before the administration

is to begin so that the patient may be rested. It is one advantage of the method that the patient lies quietly until he is unconscious, the injection being made, of course, without taking him from his bed. When the injection has been made the tube may be clamped and left in position. The pressure in the intestine never reaches 20 mm. Hg., according to Gwathmey. If narcosis becomes too deep it is easy by freeing the clamp to withdraw what remains of the mixture. If respiratory arrest occurs, Gwathmey recommends that a bag one-third full of carbon dioxide be applied to the face and artificial respiration performed. If narcosis is insufficient it can be deepened by merely placing a towel over the patient's face, which to some extent prevents him from getting rid of the ether. The breath smells of ether soon after the injection is begun, showing that the drug is eliminated by the lungs from the first. When operation is over two tubes are passed high up into the colon, cold water soap-suds being introduced through one tube and drawn off through the other ; 2 to 4 ounces of olive oil should then be introduced into the rectum and the tubes withdrawn (Gwathmey). The washing out after operation has often been omitted when the narcosis was not very deep, in order that recovery might not be too rapid. Gwathmey records over 500 administrations without any serious drawback. Buxton, referring to his vapour method, states that he has met with grave complications in a few cases, but with no fatality which should be referred to the method of anæsthesia. Clifton Luke [1] raises the theoretical objection to colonic oil-ether anæsthesia that a powerful solvent is placed in contact with variable amounts of highly toxic intestinal contents, and that definite quantities of toxin may be helped to re-enter the circulation. On the other hand, some anæsthetists claim the germicidal properties of ether and their effect on intestinal organisms as one of the especial advantages of rectal administration. Luke also avers that the position of the fluid in the intestine has a marked influence on absorption and that it is impossible to know how high the mixture has gone. Reverse peristalsis might send it to the cæcum and make recovery of it impossible. The corneal reflex should not be allowed to disappear during rectal anæsthesia. If it does, or if stertorous breathing or cyanosis appear, the mixture must be allowed to escape. Respiration generally is of a very quiet type, with absence of all obstructive spasm or congestion and with freedom from mucus and saliva. The blood pressure is well maintained. Recovery in a large proportion of cases takes place without nausea or vomiting. Excitement during induction does occur, but less frequently than with inhalation anæsthesia. Precautions to keep

[1] *Med. Record*, May 9, 1914, p. 839.

a free air-way are often necessary. If the tongue is allowed to obstruct the larynx, cyanosis and too deep an anæsthesia rapidly appear.

Ether without oil has been used in a few cases by Manine and Le Page. They regard 100 c.c. as the maximum amount to be introduced, and having run in the ether they leave the catheter *in situ* with a clamp on it. Anæsthesia arises more quickly than from the oil mixture. It is said to be of light degree, but to last about two hours.

Intravenous administration of ether may be carried out with advantage on patients in whom it is desired to increase the volume of the circulating blood during operation. Those suffering from severe shock or hæmorrhage, and the starved, cachectic sufferer from gastric carcinoma who is to have a gastrostomy performed are examples. The risk of waterlogging the lungs by throwing large volumes of extra liquid into the veins is never to be overlooked when this method is under consideration.[1] Because of this risk the process is well adapted only to those subjects that are easily rendered anæsthetic, and in whom, therefore, very large quantities of the ether solution will not have to be infused. The risks of sepsis, of thrombosis, and of air embolism appear to be negligible when due care is exercised. The kidneys and the lungs must be known to be sound before this method is chosen, and plethoric patients needing great quantities of anæsthetic must not be treated with it. Granted the suitability of the subject, intravenous infusion has obvious advantages for operations upon the head and neck. It enables the anæsthetist to remain entirely away from the operative field. Any measure which, in an operation for removal of tongue, upper jaw or larynx, for instance, leaves the operator's field of action entirely unencroached upon by the anæsthetist, is, *cæteris paribus*, a superior method. At the same time it must be remembered that the necessity for keeping the air-way clear remains however ether is being introduced. Its elimination by lungs and mouth must not be obstructed, and local measures on the part of the anæsthetist may be required for this purpose. Other obvious advantages of an infusion method are—(1) that the drug being put directly into the circulation, instead of indirectly *viâ* the lungs by inhalation, dosage can be accurately measured; (2) irritation of the upper air passages is avoided. Ether infusion is better adapted to hospital than to private practice. The method was introduced by Burckhardt in 1910. Experiments had led him to regard 5 per cent. as the proper strength of solution. When he had tried 10 per cent. ether in normal saline he caused hæmoglobinuria. Buxton also has seen

[1] Erimbaum, *Brit. Med. Journal*, 1911, 2, p. 1281.

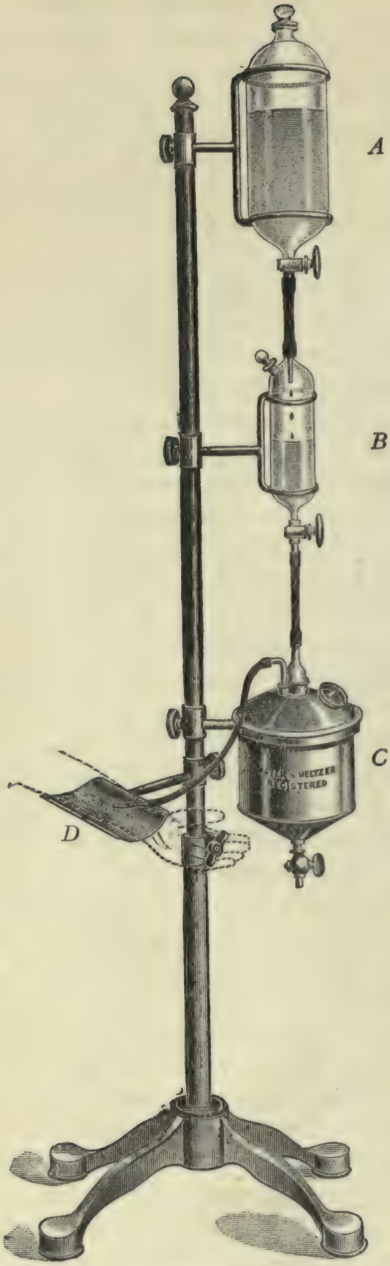


FIG. 19.

hæmolysis follow the use of 10 per cent. solution. Burckhardt's method involved interruptions of the inflowing stream. He introduced enough solution to produce anæsthesia and then no more until signs of recovery were obvious. This interrupted infusion increased the liability to clotting around the cannula. Rood,[1] who first used the method in this country, improved upon Burckhardt's technique. He showed that a strength of 7·5 per cent. was often desirable, and he designed an apparatus that allows continuous infusion and delicate graduation of the rate of flow (Fig. 19). The solution is prepared by shaking ether in normal saline until it is thoroughly dissolved.

The whole of the apparatus is sterilized by boiling, and is then put together. The reservoir is nearly filled with the solution and is fixed 8 feet above the floor. The solution flows through the indicator, then through a warming chamber into the cannula, and so into the vein. The indicator consists of a cylindrical bulb with a capacity of 8 ounces. When the apparatus is working the lower half is full of the solution, while the upper half contains air. The solution flows from the reservoir into the bulb through a pipette and drips on to the surface of the fluid below. The system being a closed one, the pressure within it is transmitted through the indicator by means of the air contained therein. Hence it follows that the rate at which the solution drips from the pipette furnishes a satisfactory index of the rate at which it is entering the

[1] *Brit. Med. Journal*, Oct. 21, 1911, p. 975.

vein. The flow is entirely controlled by one tap placed immediately below the indicator.

A, reservoir with stopcock.
B, indicator with stopcock and air inlet.
C, warming chamber in copper hot water receptacle.
D, arm rest.

When the apparatus is about to be used the reservoir tap is opened and the regulating chamber half filled with solution. The regulating chamber tap is then opened and a continuous flow allowed through the warming chamber until this is freed of air. When the apparatus is full of the ether saline solution the regulating chamber tap is closed and flow from the reservoir ceases. The cannula lies ready in sterilized water and attached to the efferent tube from the warming chamber.

The patient is prepared as for other general anæsthetics. In addition the skin of one arm is sterilized over the bend of the elbow, where the median basilic and cephalic veins are prominent, and the arm lies on a rest to which it may be lightly bandaged. One of the two veins is selected and the skin over it rendered anæsthetic with eucaine. It is then exposed and surrounded by ligatures and the cannula inserted into it after the manner usual in transfusing into a vein. The rate of flow is controlled by the position of the tap from the regulating chamber. By watching the drip from the reservoir into the regulating chamber it is easy to estimate how fast solution is entering the vein. At first the solution is allowed to run in a regular stream, and this is continued during induction, which is generally complete in about five minutes. Then the regulating chamber tap is turned to allow drops with fair rapidity, and the rate of these can usually be lessened as time goes on. Three to three and a half pints of 7½ per cent. ether saline are, roughly speaking, the most that can be given safely.

Coburn has pointed out an objection to the intravenous method which he holds applies also to rectal infusion of oil-ether. There is in these methods an increase in the toxication by ether. The amount of ether within the system remaining constant, any increase in the volume of circulating fluid decreases the depth of narcosis. Therefore in the intravenous method, in order to maintain surgical anæsthesia, the amount of ether required is increased in the proportion that the amount of saline solution introduced bears to the original volume of the blood. In this method and in the rectal method the amount of ether in the circulation is increased and the margin of safety between surgical anæsthesia and respiratory paralysis is reduced.

The *intravenous injection of ether vapour* has been tried on

animals.[1] The femoral or saphenous vein was selected, but it was found that so rapid was the elimination of the vapour by the lungs that anæsthesia could not be obtained unless the head of the animal was enclosed.

Oral administration of ether by swallowing was introduced for obtaining analgesia during painful dressings and minor operations in military hospitals. Where so large a number of patients needed dressings involving pain, especially the dressing of wounds accompanied by fractured bones, it was a great advantage to possess some method by which, without moving the patient from his bed or subjecting him to an inhalation anæsthesia, he could be kept quiet and could be manipulated without pain. The saving of medical man-power was also valuable.[2] Gwathmey and Karsner, after numerous experiments with rabbits in which they tried to produce analgesia by a variety of drugs inserted into the stomach, found the best results with ether and olive oil. The oil, however, produced gastritis in rabbits, and a less irritating medium was sought. Ether, it was held, could safely be tried on the human subject as the anæsthetizing agent, since it was known to have been frequently swallowed by the mouth without causing structural damage. The formula

Ether	aa ℥iv.
Liquid paraffin	
Aq. menth. pip.	♏v.

was finally arrived at, and successful results followed its use. It was given sandwiched with port wine. First a mouthful of the wine is held in the mouth and then swallowed. The ether mixture is then immediately swallowed and followed at once by the rest of the ounce of port wine. After about ten to fifteen minutes drowsiness or light sleep comes on and proceedings otherwise painful are quietly tolerated. True anæsthesia is not aimed at and is not obtained. Often there is not even true unconsciousness, but the analgesic stage of narcosis is reached and pain is not appreciated. Chloroform in ½-drachm doses was sometimes added to the above without harm. Vomiting after this form of administration was infrequent.

Intra-muscular administration of ether,[3] although it has succeeded in causing anæsthesia, offers no advantage over other methods. Moreover, even among the comparatively few occasions on which it has been tried, it has been followed more than once by abscess in the injection site. It does not appear, therefore, to be worth further trial.

[1] *Soc. de Biologie, Comptes Rendues et Mémoires*, 1914, Vol. 77, p. 128.
[2] *Brit. Med. Journal*, March 2, 1918, p. 254.
[3] Walther in *Bulletin Médical*, May 29, 1912.

Subcutaneous administration of oil-ether was experimented with by Gwathmey.[1] He employed guinea-pigs, and found that the maximum safe dose was ·74 c.c. per 100 grms. of body weight. The injection was made at the back of the neck and against the direction of the hair, which was not removed.

Clinical Effects of the Administration of Ether.—The difference in the symptoms produced by ether given in different ways has been to some extent already indicated. We have seen, for example, that a slow open method produces less spasm than a closed one, that rectal administration is commonly unaccompanied by excitement, and that intravenous infusion is inefficient with highly resistant subjects. We must now, however, give a fuller account of the effects produced from the beginning of administration, through the stages of narcosis, and during anæsthesia and recovery, and of the after-effects that may arise. The stages of narcosis, although they often pass so smoothly one into another as to be scarcely separable, can sometimes be clearly distinguished during the administration of ether.

The *first stage* is accompanied by a feeling of exhilaration and increasing warmth on the patient's part. The odour of the drug is resented unless it is very gradually administered, in which case there is no holding of the breath or swallowing movement at this time. If the vapour is too strong there will be coughing or voluntary holding of the breath or retching. In the presence of a properly weak vapour the breathing continues without interruption and becomes deeper and quicker. The face flushes, the conjunctivæ become suffused, and the pulse is increased in vigour and rapidity. The pupils become large, but not stationary in size. There may be talking, but this is not so common as during chloroform inhalation. Unconsciousness comes suddenly, and the *second stage* may be marked by excitement. There may be sudden and violent movements of the limbs or of the entire body, apparently prompted by the dreams racing through the brain. It is at this stage that it is so necessary to have a third person present to control the unconscious patient and prevent him coming to harm. He may suddenly hurl himself from the table. More commonly he makes partial attempts at sitting up and at removing the inhaler or mask. Persons commonly engaged in active pursuits often give evidence of it at this stage. The polo-player shouts inarticulate advice and rides furiously, the soldier goes "over the top" with a yell. These phenomena are exceptional. The alcoholic, however, will rarely pass through this stage without excitement and spasm of muscles. The majority of people go quietly through this period of early

[1] *N.Y. Med. Journal*, July 19, 1919, p. 96.

unconsciousness, a little rigidity of the limbs and of the muscles about the jaws being usually the only symptoms. The pupils generally diminish in size, but are still mobile. Breathing and pulse continue to be quicker and more vigorous than in the ordinary waking state. Perspiration begins to break out on the forehead and mucus and saliva collect in the mouth. Interruption to the breathing not uncommonly occurs through the swallowing of these fluids as they reach the pharynx and through spasm of the jaw muscles. Rhythmical muscular contractions causing a fine tremor or clonos may affect one or more limbs. As the narcosis increases all these muscular activities are replaced by relaxation, and with slackened jaw muscles and flaccid limbs, stertorous breathing announces the patient's entry into the *third stage*. Respiration is now quite regular and less hurried than in the second stage, but faster than in ordinary sleep. The pulse, too, is correspondingly quickened. Its force is well sustained. The conjunctivæ are insensitive, the pupils about half-way between full dilatation and contraction, and the corneal reflex sluggish but still present. After a few minutes it will be gone. The pupils react to bright light. The globes of the eye are slightly moving or motionless, but eccentric. Sometimes they give faint twitches, due, no doubt, to slight spasmodic contractions of one or other of the motor muscles. Later they are generally quite still and symmetrical in position. A rosy *rash* often appears on the neck and chest, sometimes also on the thighs, during the early stages of ether narcosis. It is most obvious in the fair-complexioned and rarely lasts more than about ten minutes. It may be very like a measles rash, and is of no importance except for the possibility of its being mistaken for the latter by those who are unaware of the fact of its liability to appear owing to ether. On one occasion this rash appearing on a child—and it is often especially obvious with children—led to the patient being returned to the ward as a case of measles instead of undergoing the expected operation.

The patient is now ready for most operations. For abdominal sections and operations on specially sensitive parts it is best to wait a little longer till the cornea is quite insensitive. *Testing for the corneal reflex* must be done correctly, or it will mislead. One finger alone should be used. The lid is held gently up, and then the pulp of the finger is drawn briskly but lightly over the pupil. A slight flicker of the upper lid against the finger is at once felt if the reflex is still active, and the lower lid is seen to move faintly too. The reflex must not be frequently tried for, or the cornea loses its sensitiveness and is no longer a true guide. A common mistake is to hold the lid back and then dab a finger tip on to the cornea. A response will often fail

to be elicited in this way, when a gentle stroke across the pupil in the proper fashion will show at once that the reflex is still active. This condition of surgical anæsthesia may be maintained with ether over long periods of time. In practice the nature of the operation in progress plays a great part in determining the onset of symptoms of over-dose. The greater the loss of blood, the more powerful the shock-producing stimulation caused by the surgical procedure, and the more trying the necessary posture of the patient, the sooner will the true third stage of anæsthesia give way to phenomena which represent the fourth stage of narcosis—the stage of over-dose. If, however, operation is not severe, and if hæmorrhage is not excessive, the blood pressure and body temperature may be only slightly lowered, although anæsthesia is kept up for two hours or more. *The respiration* will continue to be faster than normal, but it will be free and uninterrupted if the patient is properly managed. Ether stimulates the respiration. During induction the breathing is commonly both quicker and deeper than ordinary respiration, whether in consciousness or in sleep. When anæsthesia is reached and the respiration has settled down to a regular automatic action, it is still faster than normal, but in practice the increased rate is largely dependent upon the operative interference, for it slows down notably when this is finished. If the respirations are counted during an operation, it will commonly be found that a quiet, apparently slow rate of breathing is really a good deal faster than normal, twenty-six to thirty to the minute being quite usual. By far the most common cause of respiratory difficulty during ether narcosis is *local obstruction in the upper part of the respiratory tract*, above the larynx. This is caused either by spasm or by a relaxed congested tongue being allowed to fall back with each inspiration and obstruct the entry to the larynx.

Spasmodic obstruction is commonly met with early in ether narcosis. The jaws may be tightly clenched and the tongue spasmodically retracted with each inspiration, while the nose affords an imperfect or useless air-way. Under these circumstances merely pushing forward the lower jaw does not suffice to bring the base of the tongue away from the upper aperture of the larynx. The mouth must be opened, and then it may be possible to lever the tongue forward by firm pressure behind the angle of the lower jaw, either behind that which is lying lowermost or behind both angles. If this is not successful, the tongue must be held forward till with a deeper narcosis the muscles relax. In the other form of obstruction occurring in full anæsthesia it is always possible to secure a free air-way, either by keeping the lower jaw well forward, which can generally be managed by using a small

prop between the teeth as a fulcrum and tilting up the chin, or else by inserting an artificial air-way. The latter device is very often necessary when the Trendelenburg position is in use. With edentulous subjects in the Trendelenburg position an air-way should always be used. Obstruction from *laryngeal spasm* is far less common than during chloroform narcosis. It may arise owing to the presence of mucus. More commonly it is caused reflexly, as, for instance, by stretching the sphincter ani. A harsh inspiratory spasmodic noise with exaggerated diaphragmatic action, the so-called "rectal cry," is the evidence of laryngeal spasm. Deeper narcosis will sometimes get rid of it. In some patients, however, it persists as long as the causative surgical procedure goes on, no matter how deep the anæsthesia. When it is caused by mucus the back of the pharynx must be rapidly cleared with a sponge. When, as sometimes happens early in narcosis, it is due to too strong an ether vapour, diminishing the strength of this will put an end to the crowing breathing. The *circulation* is well maintained during ether narcosis. The pulse is more rapid than normal, but of good volume, and the blood pressure falls but a little. Consequently hæmorrhage is more troublesome to the surgeon than when less stimulating anæsthetics are used. When, however, as in the open methods, ether is given with plenty of air or oxygen, the vascularity is not nearly so pronounced as during closed methods of administration.

Reflex depression of the pulse, as of the breathing, is rarely a serious matter during ether narcosis. Reflex syncope during surgical anæsthesia from ether may be said never to occur. The respiratory obstruction above referred to, whether due to spasm from ether or to reflex causes, may lead to circulatory failure if it is not corrected. Such failure may, in the presence of a diseased or badly acting heart, become complete. Indeed, it may be said that when heart failure occurs during ether narcosis there is almost invariably an asphyxial element in the causation. Unless happening at the end of a lor g operation when the patient has received very large amounts of the drug, fatalities appear to have always been associated with preceding cyanosis. It has needed the reinforcement of asphyxia to produce heart failure under ether. The danger of *over-dose* pure and simple is chiefly to be apprehended during long operations. The open method is then commonly in use, and it is easy, owing to the absence of cyanosis, for the anæsthetist to give the drug to excess. Moreover, it is often difficult to discriminate between the effects of the surgical trauma and those of the prolonged, excessive inhalation of ether. Pallor, clammy skin, shallow breathing, dilated pupils, globes rolled back behind partly opened lids, all these obvious

symptoms may be due to surgical shock. When, in addition, the corneal reflex is entirely absent, the anæsthetic is generally playing a large part in their production. A patient in whom the features just enumerated are due to surgical trauma may, and often will, retain a perfectly brisk corneal reflex if the anæsthetist has been sufficiently sparing of his ether. Then the eye condition keeps him assured that he has to do with a condition of pure shock or hæmorrhage, as the case may be, and that a toxic over-dose of ether is not present. Unfortunately, in many operations a narcosis is needed so deep that the corneal reflex is quite gone. This distinction between shock and over-dose is not then available. It has been in severe operations about the head and neck, where the deepest narcosis is not usually required, that the present writer has found the corneal reflex of such service. In abdominal operations its aid is not to be expected, for it usually must be kept in abeyance throughout.

In order to *avoid over-dose* and keep the patient in the third stage of surgical anæsthesia the anæsthetist has several guides, as will be understood from what has already been written. Before allowing any operation to begin he assures himself of the presence of three cardinal signs of ether anæsthesia—*stertorous breathing, relaxed limbs*, and *absent conjunctival reflex*. During maintenance of anæsthesia his chief and constant guide is the breathing. He must be able throughout to see or to hear how this is going on. If he can neither hear nor see the respirations, as sometimes happens during head and neck operations, he must be able to feel them by a hand at the lower chest or epigastrium. When narcosis is getting lighter the respiration will show it. There will be interruptions due to *swallowing movements*, or there will be faint attempts at coughing. Broadly speaking, noises with expirations show light, noises with inspirations deep, narcosis. A prolonged straining with expiration, however, is sometimes present in very deep narcosis. This form of breathing is often present in asthmatic subjects even when they are not too deeply under the anæsthetic. The breathing becomes slower and quieter if narcosis lightens under ether. If with gentler breathing and swallowing present steps are not taken to deepen the narcosis, retching and vomiting may quickly follow. With these respiratory indications of light narcosis there are further guides in the behaviour of the eye. When anæsthesia is fully established the pupil is of medium size (4 mm.) and reacts to light. Variations in the size of the pupil must not be regarded as any indication of the depth of narcosis until anæsthesia has been present for at least ten minutes. If narcosis diminishes the pupil also diminishes and reacts more briskly to light. The corneal reflex also returns if it has been

abolished, and if not, becomes more readily evoked than it was. If, on the other hand, more ether is given and narcosis deepened, the pupil steadily grows in size and becomes only faintly active to the stimulation of light. The globes are stationary in the midline in deep narcosis. They are eccentric or moving when anæsthesia is light. The more ether is given the more vigorous and faster the respiration, unless the drug is pushed to the point when a toxic effect on the respiratory centre comes into play. Regarding the reflexes as guides to the depth of narcosis, we must not lose sight of the fact that their order of disappearance is not constant for different individuals. As a rule, for example, when the corneal reflex is gone the laryngeal has gone beforehand. There will be no coughing if the cornea is insensitive. Yet now and then the opposite is true. The relative sensibilities of the two regions may be unusual. The larynx may be in an exceptionally irritable, sensitive state. When that is so it will retain its reflex sensibility during a degree of narcosis which would render the normal larynx irresponsive to any stimulus. The sensitive larynx may then remain active to stimulus and cause a cough even after the corneal reflex has been abolished.

Ether clonos during the second stage of narcosis has been referred to. The same phenomenon appears sometimes during full anæsthesia. Usually, however, this only happens if the narcosis is comparatively light. It has appeared, nevertheless, in the writer's experience in the presence of an insensitive cornea. It is commonly caused by some alteration in the position of a limb, and very often occurs when the patient is put into the lithotomy position. Deficient aeration of the patient makes the appearance of clonos more likely. In the experience of Holroyd it is limited to men. If it persists in spite of deep narcosis, the best plan is to replace ether by chloroform until the spasm ceases. T. Rietz attributes this phenomenon to cerebral excitation brought about by the narcotic circulating in the blood. He therefore suggested pressure on the carotid as a treatment. Trying this in twenty-nine subjects, he stopped the tremor at once in nineteen, in five imperfectly, and in five not at all. The pressure must be firm and sometimes bilateral.[1]

Perspiration is often profuse during ether narcosis. This may add seriously to the lowering of the body temperature. When it occurs the skin must be rubbed dry at the end of operations and dry coverings replace those that have received the sweat. Perhaps the chief advantage of using atropine before ether is that it prevents excessive perspiration.

The first noticeable feature when operation is finished and

[1] *Lancet*, Jan. 21, 1922, p. 141.

ether is withdrawn is the quiet breathing which replaces the more noisy, vigorous respiration of ether narcosis. Symptoms of *recovery* are generally seen soon after ether ceases to be absorbed. If the administration has been but a short one the conjunctival reflex regains its activity almost at once, and swallowing movements, retching, and vomiting soon follow. One act of vomiting in which mucus and saliva and the gastric fluid are ejected before the patient has regained consciousness is a very usual event. It is soon followed by voluntary movements and return of a blurred consciousness. The taste of ether lingers in the mouth and the smell of it in the breath. Susceptible persons may be troubled by this for twenty-four hours or so even after a short inhalation, noticing ether every time they take anything by the mouth.

The stages of narcosis are more or less definitely traversed again in reversed order during recovery. Thus those patients who have shown great excitement or much spasm during the second stage may give similar trouble before consciousness is fully regained. Special precautions must be taken to ensure that clenching of the teeth, with blocking back of the tongue and occlusion of the larynx, does not occur when obstructive troubles have been present during induction. The patient should be returned to bed with a prop between the teeth and should be placed well on the right side with a pillow behind the back to keep him in a purely lateral position. He must not be left alone until he is so far roused that he answers when spoken to. Asphyxia, either through inhalation of vomited matter (liquid or solid) or through complete occlusion of the upper opening of the larynx by a tongue congested and retracted behind clenched teeth, has occurred during the spasmodic stage of recovery in patients left unattended after ether anæsthesia. The possibility of this accident must be especially borne in mind when there is a chance of blood accumulating in the pharynx, as after operations for removal of tonsils and adenoids. The lateral position until consciousness has returned is the chief safeguard.

Vomiting after ether occurs to some extent in a large proportion of patients. After short administrations it is often only the one pre-conscious vomit that is unknown to the patient, and is, as a matter of fact, helpful to him by clearing his stomach of swallowed ether-laden mucus and saliva. After longer administrations, or even after short ones in those particularly susceptible, vomiting and retching may be repeated several times during the first twenty-four hours after operation. More rarely the nausea and vomiting persist through two or three days, recurring with every attempt to take food or drink by the mouth. In 572 unselected

cases of "gas and ether" I found complete absence of sickness in 122. Open ether preceded by atropine gave better results, for out of 250 patients 98 were not sick at all. Sickness after ether rarely takes the serious form described under post-anæsthetic toxæmia.

Protracted vomiting after an abdominal operation, or after any operation on a patient who has previously had an abdominal section, should always arouse suspicion that some mechanical cause may have arisen. The ordinary post-anæsthetic vomiting may lead to mechanical obstruction of the bowel, and this condition may be unsuspected if the sickness is thought merely due to continuance of the effect of the anæsthetic.

An example of this accident occurred in a woman of forty operated on for varicose veins. Six years previously she had undergone an ovariotomy. Nothing unusual occurred at the removal of the veins, which was effected under ether preceded by ethyl chloride, and lasted fifty minutes. Vomiting after recovery was frequent and was accompanied by some abdominal pain, which was attributed to the repeated emesis. At the end of thirty-six hours, vomiting having not ceased, there were an attack of diarrhœa, rapidly increasing feebleness, convulsions and death. *Post mortem* septic peritonitis was found, most intense in the neighbourhood of an adhesion between the old ovariotomy stump and a coil of small intestine. Post-anæsthetic vomiting was held to have started the trouble in the presence of the abnormal condition due to the previous laparotomy.

Routine treatment for mitigating these unpleasant after-effects of ether consists in—(1) giving an enema of half a pint of water containing a drachm of potassium bromide and 10 grains of aspirin as soon as the patient is back in bed and before consciousness returns. The above dose is for the average adult male, and must be modified to suit the individual patient. Rectal injections of water are useful to allay *thirst,* which is a common consequence of the loss of fluid due to operation and anæsthesia, apart from the treatment of vomiting. (2) If vomiting occurs after consciousness has been regained give at once a drachm each of sal volatile and sodium bicarbonate in a glass of hot water. (3) Let the patient's face be covered by a handkerchief on which is sprinkled either eau de cologne or vinegar. (4) Whenever possible, let the patient be propped up in a sitting position after consciousness has returned. (5) Let the room be warm, ventilated, darkened and quiet. (6) During the first twelve hours after operation let pieces of fresh orange or lemon or pineapple be sucked and nothing else taken by the mouth. This last injunction does not apply, of course, to recovery after short minor operations on healthy people. Feeding with them can be regulated on common-sense lines according to the patient's desires. Infants are allowed to have half a usual feed as soon as they begin to cry, after operation, supposing that this has been done at what would have been a feeding hour.

When vomiting continues nothing should be given by the mouth, and the stomach should be washed out with weak bicarbonate solution and the patient given nourishment *per rectum*. A number of drugs have been tried for quelling vomiting after ether. None of them appears to have any specific action. Iced champagne in small doses and hot coffee have both been of service. Drop doses of tincture of nux vomica, of tincture of iodine in teaspoonfuls of water, of dilute hydrocyanic acid, or of vinum ipecacuanhæ have been tried with apparent success at one time and no influence at another. Small hypodermic injections of morphia, which in some patients are undoubtedly responsible for starting sickness, are, on the other hand, sometimes effective in quelling persistent vomiting. Ether sickness is more easily prevented than cured. It is comparatively rarely a formidable sequel to ether narcosis when everything is done to minimize the amount of ether used. The use of continuous nitrous oxide and oxygen or of local analgesics in combination with ether often prevents vomiting after abdominal operations, the only operations after which ether vomiting is at all likely to be a serious complication. We are obliged to be purely empirical in our efforts to combat the vomiting if it occurs, because we are in ignorance of the exact way in which it is caused. Probably this is not always the same. The stomach, the vomiting centre, the general "nervous state," all may, it appears, be the chief sources of the trouble in one patient or another. Consequently washing out the stomach, bromides, or a mustard-leaf to the epigastrium may each have success on its proper and different occasions.

Ferguson recommends that warm olive oil should be passed into the rectum when the patient returns from operation. The oil is said to hasten the recovery of power to resist infection. This power, residing in the phagocytes and in the serum of the blood, is lowered by ether narcosis.

Hæmatemesis after ether is not very uncommon. It occurs usually in florid individuals who have required large amounts of ether and have displayed spasm and congestion to an inconvenient degree. The blood is probably oozed from the mucous membrane of the gastro-intestinal tract. It is generally brought up as a beef-tea-like fluid. This vomiting of altered blood after ether does not continue long and is not associated with serious symptoms. It is sometimes pronounced, as might be expected, after a gastro-enterostomy. On many occasions it has followed operation for radical cure of hernia.

Hiccough sometimes gives trouble after ether anæsthesia, especially if the stomach has been operated on or manipulated. It usually ceases within a few hours, and if needing treatment

should be treated in the same way as ordinary post-anæsthetic vomiting. When accompanied by increasing flatulence, hiccough may be a serious symptom. It is then not due to the anæsthetic, but to intra-abdominal trouble or to the general state of the patient.

Conjunctivitis has followed inhalation of ether.[1] This is not due to the vapour, or even to a drop of the liquid entering the eye, but to the face-pad having been allowed to become wet with ether and to remain in contact with a partly open eye.

Acute dilatation of the heart after ether has been said to occur. The symptoms are breathlessness and extreme rapidity of the heart's action, the attack coming on suddenly. Levine [2] believes that these attacks are paroxysmal auricular tachycardia, not dilatation. He alludes to seven instances, in six of which the attacks occurred from twenty-four hours to nine days after the operation. The abnormal state of the heart was controlled by the use of digitalis.

The *post-operative shock*, which is not very uncommonly seen after long operations performed under ether, is a mixed effect of operative trauma and ether inhalation. The continued stimulus of operative procedures results eventually in exhaustion or functional incapacity of the nerve centres.[3] The same result is reached by a different route through the long-continued depressing effects of prolonged inhalation of ether. So far as the anæsthetic is concerned, the chief treatment is preventive. The exhausted state is to be avoided by careful curtailing of the amounts of ether administered (see also p. 329, under " Shock "). Treatment of the condition in so far as it is the result of ether has been shown to be effectively carried out by inhalations of carbon dioxide. Yandell Henderson [4] shows that the influence of this gas is exerted particularly on the venous return to the right heart. The insufficiency of this return is a prime factor in post-operative depression. Recovery of the circulation and a rapid return to normal arterial pressure are to be expected by restoring to the blood and tissues the carbon dioxide lost during anæsthesia and operation. This is the result which Henderson, in conjunction with H. W. Haggard and R. C. Coburn, claims to have obtained. The beneficial effects which they observed were :

(1) Increase of breathing, which rapidly ventilates the anæsthetic out of the blood.
(2) A powerful stimulant effect on the circulation, particularly

[1] *Journal Amer. Med. Assoc.*, Vol. 70, p. 83.
[2] *Ibid.*, Vol. 75, No. 12, p. 795.
[3] *Year Book of Anæsthesia*, 1917–18, p. 104, W. E. Munns.
[4] *Journal Amer. Med. Assoc.*, March 20, 1920.

on the venous return, and a rapid restoration of arterial pressure without subsequent relapse.

(3) Decrease of post-operative nausea, vomiting and thirst.

(4) Restoration of intestinal tone.

The *intestinal distension* sometimes seen after long administration of ether has been attributed to excessive loss of carbon dioxide, leading to a paralytic condition and loss of tone of the muscular coats of the bowel. (There is experimental evidence to support this view. Normal peristalsis was obtained in dogs if long ether inhalations were accompanied by some re-breathing.[1]) This may be corrected by the carbon dioxide inhalation treatment. An 8 per cent. atmosphere of the gas is administered. The apparatus necessary is illustrated in the article referred to,[2] which the reader is recommended to consult. So far only a few patients have received this treatment, but the results fully justify further trial. Other measures to combat the post-operative distension are use of a rectal tube and hypodermic injections of eserine or of pituitrin. On some occasions small injections of morphia have succeeded after other remedies had failed.

The occurrence of *thrombosis* after ether anæsthesia is attributed by some to the effects of the drug. We have seen that the coagulation time of the blood is lessened by ether (p. 77). Probably more effective still is the loss of fluid which occurs during long narcosis. It is important from this point of view that patients should drink water freely during the twenty-four hours preceding operation. Lapthorn Smith [3] recommends slow administration of rectal enemata during operation, 20 ounces of salt solution being given for every half-hour of operation. An important point in after-treatment is to allow the patient to move about freely in bed, to sit up for meals and to get up for defæcation. Stagnation of the blood is thus avoided. Pulmonary embolism was more frequent in past days when rigid immobility was insisted on after abdominal operations and when water-drinking during recovery was strictly limited. The occurrence of *pulmonary infarcts* during recovery after ether anæsthesia is dealt with later. Moxon [4] relates a case in which he attributed thrombosis of a branch of the coronary artery to the effect of ether.

Disturbances of the *kidney* due to ether are rarely serious. Slight albuminuria is very commonly caused, but is of short duration. In a series of 400 urines examined after operation

[1] *Journal Amer. Med. Assoc.*, Vol. 45, No. 1, pp. 2—5.
[2] *Ibid.*, March 20, 1920.
[3] *Lancet*, June 8, 1918, p. 644.
[4] *Ibid.*, April 17, 1886, p. 731.

Hogan [1] found 26 per cent. with albumen and casts. In these cases there was very low output of chlorides. Post-operative symptoms, nausea, vomiting, headache and "gas-pains," were found to vary in intensity with the intensity of the urinary changes. Forty-nine per cent. of these urines showed acetone or acetone and diacetic acid, and no less than 94·2 per cent. showed "marked increase in the hydrogen acidity." Hogan requires all patients before operation to be passing at least 1,500 c.c. of urine a day, and this must be alkaline to litmus. Reduced urinary output after anæsthesia is associated with increased absorption by the tissues of water from the blood. This is a consequence of the raised acid content of the tissues due to their diminished oxygenation. The œdema which ensues is held responsible by Hogan for post-operative symptoms. By preventive measures which assure the presence of water and of alkalies in sufficient quantity he controls the post-operative symptoms. Before operation he has an enema administered containing an ounce of bicarbonate of soda in a quart of water. Experience of the use of ether with patients who are already passing albumen in the urine does not show that there is danger of greatly increasing the albuminuria.

Disorders of some part or parts of the *respiratory tract* are not uncommon after ether, and may be serious. It is not easy, however, to decide to what extent ether is alone or even in part responsible for the affections described as "ether pneumonia." Observation of large numbers of patients who have respiratory trouble after operation brings out one fact more prominently than any other, and that is that the site of the operation has more influence than the nature of the anæsthetic in determining the onset of some respiratory sequel. Abdominal operations are almost the only class of operation that is at all commonly followed by complications within the chest. These complications may occur after laparotomies, whatever anæsthetic is used. They have followed chloroform, spinal, and purely local anæsthetics. G. H. Griffiths writes: "The number of chest complications under novocaine anæsthesia was almost as great as those that followed general anæsthetics." [2] Romanis [3] refers to the occurrence of pneumonia in five patients operated on for goitre under local anæsthesia, and remarks: "It would appear that in post-operative pneumonia the anæsthetic is by no means necessarily the cause." Much light has been shed on lung troubles subsequent to operation by Pasteur's description of

[1] *Amer. Year Book of Anæsthesia*, 1915, p. 172.
[2] *Lancet*, May 1, 1920, p. 961.
[3] *Ibid.*, Mar. 11, 1922, p. 471.

massive collapse, its association with trauma and anæsthetics, and its relation to post-operative pneumonia.[1] Collapse is that condition of the lung, or part of the lung, in which it is completely deprived of air content, and massive collapse Pasteur describes as a " total deflation of a large area of lung tissue, of sudden onset—in the absence of signs of obstructed airway or of known causes of compression—due to failure of inspiratory power and attended by definite physical signs and symptoms." Partial deflation of the pulmonary bases is frequently met with after abdominal operations, and signifies loss of efficient inspiratory force. It may be caused by the impaired mobility or actual stillness of the diaphragm due to the pain of breathing fully or of coughing in the presence of an abdominal wound. Although this condition is a predisposing cause of patchy collapse of the bases of the lungs, and plays probably a prominent part in the causation of many " ether pneumonias," it has little in common, according to Pasteur, with massive collapse. The latter condition is one-sided ; if it were due to post-operative limitation of the movement of the diaphragm it should occur on each side. On the other hand, failure of respiratory force is an essential cause of massive collapse, which is seen with paralysis of the diaphragm or intercostal muscles after diphtheria. Pasteur concludes that post-operative massive collapse is the result of reflex arrest of action of one half of the diaphragm. The afferent path of the reflex is some branch of the vagus nerve, for the initial disturbance, whether trauma, disease, or surgical activity, has always lain within or close to the area of distribution of some branch of this nerve. Injury of a nerve at operations suggests itself as a possible starting-point for the reflex. This idea is supported by the contention that massive collapse occurs more frequently after the use of a large incision and division of muscles than after small incisions with no such cutting of muscles.

Post-operative massive collapse is of sudden onset, and is unilateral. The attack may be so sudden and intense that it suggests embolism or pneumothorax. More commonly the symptoms resemble those of pneumonia or of heart failure, or a combination of these. In children or healthy young adults there may be latent collapse with no symptoms although the physical signs are well developed and unmistakable. Massive collapse is rarely fatal in the absence of surgical sepsis. The physical signs are dulness, diminished vocal tremitus, silence or tubular breathing, imperfect movement of the affected side with vigorous compensatory action of the other, and displacement of the apex beat towards the affected lung. Without the last

[1] *British Journal of Surgery*, Vol. 1, No. 4, p. 587.

sign Pasteur does not make the diagnosis of massive collapse. The symptoms are pain, deep-seated in the lower part of the chest and less acute than that of pneumonia, expectoration of greenish muco-purulent material which is never blood-stained, and rise of temperature at the onset, usually up to 103° F. The attack commonly begins within two or three days of operation. It is uncommon after the fourth day. Dyspnœa lasts only for some hours, and by the end of twenty-four hours the urgent symptoms have passed. The heart, however, may not regain its normal position for several days. When infective material reaches the lung the symptoms of collapse may glide into those of broncho-pneumonia. The severity of symptoms depends not merely on the extent of the collapse, but also on the rapidity with which it occurs and on the ability of heart and lungs to adapt themselves. Thus it is that in the young and healthy there may be a complete absence of symptoms. The diagnosis from pulmonary embolism depends on the displacement of the heart and the absence of blood-stained sputum. The course of the symptoms distinguishes collapse from pneumonia and bronchitis and broncho-pneumonia.

Pasteur gives the following figures: 3,559 abdominal operations were followed by 5·6 per cent. of lung complications. In these 201 complications there were 45 deaths. There were 88 pneumonias with 36 deaths. There were 12 instances of massive collapse. From the description of the cases, however, probably 20 of those recorded as pneumonia should be described as collapse. The days of onset of lung complications were :—

First Day.	Second Day.	After the Seventh Day.
46	35	54

The complications arising after the seventh day were pleurisy, septic broncho-pneumonia, empyema, and embolism. Late complications were almost always associated with sepsis. The relation of anæsthetics to these complications was :—

Anæsthetic.	Cases.	Complications.	Percentages.
Gas and ether and chloroform	2,489	120	5·18
Chloroform	452	35	7·74
Gas and ether	475	25	5·20
Chloroform and ether	133	3	2·25

In 2,000 later cases there were 3 per cent. of lung trouble as against 5·6 in the first series. In the later series there were 19 cases of pneumonia and 19 of massive collapse, as against 68 to 32 in the first series. Complications arising after the first week are little related to the anæsthetic employed. Most of the fatalities occur in septic cases.

Pasteur made the important observation that X-rays proved laparotomy to be capable of interfering with diaphragmatic action to a very serious extent. The inhibited diaphragm does not necessarily lead to patchy collapse, but it is significant that post-operative pneumonia most frequently affects the bases of the lungs. In the presence of an imperfectly distended lung and in the

absence of effective coughing, infective material inhaled from the mouth would readily set up inflammation. It is here that the anæsthetic plays its part. Ether causes mucus and saliva to be secreted in profusion. These ether-laden liquids, even if unaccompanied by organisms, may well be the cause of broncho-pneumonia if inhaled into portions of lung which are practically motionless. If this is the true genesis of ether bronchitis and broncho-pneumonia, we should expect these affections to be less frequent since the common use of open ether preceded by atropine. This has actually occurred. Apart from abdominal operations, where, as we have seen, inhalation of infective material is probably only a secondary cause, the occurrence of lung complications after ether inhalation is much less frequent than when long administrations from closed apparatus were usual and when preliminary injections were not used to control secretions. We do not commonly now see congestion and profuse secretion of mucus in the patient on the table. Correspondingly we seldom see cough and bronchitis after ether unless in abdominal cases. In support of this contention may be quoted the experience of Mériel,[1] who contrasts the present comparative freedom from respiratory after-effects with a 5 to 6 percentage of laryngitis or tracheitis in former days. This observer gives a record of 14,820 ether administrations with no fatal lung complication. It may be recalled that the experimental proof of damage to the lungs from ether was obtained by using closed ether administration. Offergeld [2] proved that this form of administration may be followed in animals by patches of consolidation in the lungs, desquamation of bronchial epithelium and hæmorrhage into the alveoli. The danger of profuse mucus secretion within the air passages was often illustrated when ether was freely given from closed apparatus without preliminary injection. Hewitt [3] gives examples of fatality from this *mucus inundation,* and alludes to the difficulty of drawing any line between this and *acute pulmonary œdema.* The latter affection can undoubtedly be set up by ether inhalation in a susceptible subject. When that occurs, asphyxial death is brought about, not by excessive mucus secretion, but by waterlogging of the lung and secondary failure of the heart. A typical instance occurred at St. George's Hospital. Ether was administered by a house physician who chose that agent on account of the feeble state of the patient. It is permissible, in the light of what happened, to suggest that chloroform and oxygen might have been less dangerous.

[1] *Bull. Acad. de Méd.,* Paris, 1917, Vol. 77, p. 794.
[2] *Arch. f. Klin. Chir.,* 1898, Vol. 47, p. 175.
[3] " Anæsthetics," p. 378.

The patient, an anæmic woman of fifty-eight with some chronic bronchitis, was brought in with a Pott's fracture, and needed an anæsthetic for proper setting of the leg. The heart's action was regular but rapid, and there were no murmurs audible. Owing to the amount of pain present and the patient's frightened state, an anæsthetic was given at once without preliminary injection. "Open ether" was chosen and given from a Skinner's mask with two layers of domette on it. The anæsthetic was quietly inhaled, but tracheal mucus caused considerable coughing, and a slight degree of cyanosis showed itself after about four minutes. Respiration continued regular, however, and the pulse was satisfactory, so the anæsthetic was continued. When narcosis was still only light the breathing began to fail, cyanosis increased, and, in spite of discontinuing the ether, respiration grew less and less effective. At the end of fifteen minutes it ceased altogether, and, in spite of the use of artificial respiration with oxygen and injections of strychnine, no effect was produced upon the now motionless heart. The *post mortem* notes stated, among other facts :—

Trachea : Full of frothy liquid.

Pleura : Left contains small amount of clear fluid.

Lungs : Right, 23 ounces ; left, 19 ounces.

The lungs are voluminous, largely covering the heart. There are no hæmorrhages and no pleuritis. Old fibrous nodules at each apex. The lung tissue is congested and extraordinarily œdematous, containing a large quantity of fluid, which squeezes out as from a sponge.

Heart : 10 ounces, small. Right side covered by layer of fat. Chambers not dilated and valves competent. Ventricular walls thin. Myocardium brownish and soft—no evidence of fatty change in shape of striation, or to microscopic examination.

Coronary arteries : Lumen diminished. Left is a rigid tube, only admitting a needle.

The power of ether to aggravate lung trouble which is already present—for instance, to increase a bronchitis or to awaken a quiescent focus of tubercle—is undoubted. The author has seen more than one example of the latter accident, and is convinced that ether should never be employed if there is evidence of old phthisis, however completely cured it appears to be. An interesting suggestion in explanation of the lighting up of an old tubercular focus in the lung is put forward by Zueblin.[1] He states that investigations on the action of ether on the tubercle bacillus have demonstrated that it partially extracts the fatty constituents of the bacterium. Partial antigens may be very powerful. "It is not impossible that a similar process takes place in a tuberculous focus during ether anæsthesia and that undesirable effects may be due to the liberation of toxic substances."

Impaired respiration, from whatever cause, if present before operation, is a signal against the employment of ether. Particularly if diaphragmatic breathing is poor, or if the respiration is wholly costal, ether is very liable indeed to be followed by lung troubles. *Infarction* accounts for a certain proportion of the lung troubles that follow ether used on healthy subjects. It is, in my

[1] *Amer. Jour. Surgery*, 1920, Vol. 34 (Anæsthetics Supplement).

experience, especially liable to appear after operations for radical cure of hernia and after pelvic operations. Pasteur found eight cases in 3,559 laparotomies. Many instances of infarction have probably in the past been reckoned as "ether pneumonia." The attack at first resembles pneumonia, but its course is much shorter. A typical case may be cited :

C. W., 25.—A thin, rather narrow-chested man, with no previous history of illness. Right inguinal hernia. Operation, 2.30, January 22, 1910. *Anæsthetic,* "gas ether" from wide-bore Clover first fifteen minutes, then chloroform from Junker for twenty-five minutes—given by house physician. No trouble with anæsthetic ; change to chloroform made because mucus seemed excessive.

January 23. Vomited twice after consciousness. 8 p.m., complains of sharp pain in right side of chest—looks in pain ; is propped up. Temperature 100°.

January 24. Temperature 104°. Is in great distress through right-sided pain with respiration. Sputum blood tinged and greenish. Physician reports : Crackles right base ; diminished entry of air ; marked dulness ; no fluid to needle.

January 25. Temperature normal. The pain has gone. Dulness and coarse rales still present at right base, and there is still mucous expectoration. The temperature remained normal and the cough and physical signs had disappeared by the eighth day after operation.

Attacks of this kind are most liable to occur within the first week. They, as well as the massive collapse, cannot be regarded as primarily due to the anæsthetic. Whatever the power of ether to cause respiratory troubles after operation, it must always be borne in mind that impaired breathing and sepsis are still more powerful factors which must be put out of court before serious lung affections after operation are attributed to the anæsthetic. Another factor to be borne in mind is possible infection from sources other than the wound—sepsis, that is to say, which is not of surgical origin. Such sepsis may probably occur owing to organisms present in the mouth. It is very likely that the lowered resistance of the patient after operation and anæsthesia, sometimes also the transference of a sweating patient from a hot to a cool or draughty room, will render potent an infection which would be overcome in the normal condition of the body. Examination of the sputum which the author had made in several cases of bronchitis following laparotomy showed almost pure growths of the *B. influenzæ.* These patients presented the typical picture of "ether bronchitis." In each case the bacteriologist reported that "the predominant organism in direct preparations and in cultures is *B. influenzæ.*" It is probable that the nature of the anæsthetic played very little part in producing the symptoms. The organism, we may presume, was already present before operation, but in the absence of symptoms we must suppose that

the defences of the body rendered it powerless. The lowered vitality following on laparotomy and anæsthesia altered the ground in favour of the bacteria, and "ether bronchitis" resulted. In other instances the prevailing organism in the sputum has been a streptococcus or a pneumococcus.

Our knowledge of the causation of post-operative lung troubles might, it appears, be considerably advanced by systematic bacteriological examination, before and after operation, of the mouth, pharynx, and sputum. No complete investigations of this kind have apparently been undertaken. We may fairly sum up the question of respiratory complications after ether by saying that this drug is more likely than other anæsthetics to set up minor affections of the respiratory tract, but that when grave lung complications follow, if modern methods of giving ether have been employed, the trouble can rarely be attributed to the anæsthetic as a main cause. Patients subject to chronic bronchitis who are given ether should be treated afterwards with four-hourly injections of atropine gr. $\frac{1}{200}$.

Ethanesal, the administration of which is carried out exactly in the same way as that of ether, may be considered here. Broadly speaking, the clinical effects of this anæsthetic are the same as those of ether, but there are differences of degree. Thus the consensus of opinion, as far as the comparatively short experience with this agent has gone, seems to be that ethanesal given by an open method is less irritating to inhale than ether, that more of it is required to produce full anæsthesia, but that in light anæsthesia it maintains a good analgesia so that movements during this state are less apt to arise than when ether is employed to keep up an equally light degree of narcosis. In my own experience ethanesal has proved a distinctly weaker anæsthetic than ether. By that is meant that induction of anæsthesia has taken longer and that complete muscular relaxation has been maintained with greater difficulty and with larger amounts of anæsthetic than are usual when ether is employed. The effects on respiration and on blood pressure and the circulation generally I have found indistinguishable from those of ether. When ethanesal has been used in a closed inhaler the results have in all respects resembled those from ether similarly given. The subsequent taste in the mouth and vomiting after consciousness are less than with ether. The difference is not so marked, however, as when an open method is used. Then the taste left by ethanesal is often negligible and vomiting often entirely absent or of only slight severity. On several occasions the writer has had the opportunity of comparing ethanesal with ether on the same patient at two separate operations. When an open method has been used the diminution of unpleasant

taste, nausea and vomiting after ethanesal as compared with his experience of ether has been obvious to the patient. On an average it has been found that, given by the open method, ethanesal is consumed at a rate of an ounce every nine minutes, a double layer of domette being used on the mask. In a wide-bore Clover's inhaler the average for adults was between 6 and 7 ounces per hour. It has been claimed for ethanesal that it can be used without harm on patients suffering from respiratory affections which would preclude the employment of ether.[1] My own observations do not support this contention, and other observers also have found that ethanesal is quite potent in causing mucous and salivary secretion. It is unlikely, therefore, to be devoid of effect on the lower respiratory passages. It would appear that the claim has largely been based on the result of operations performed under gas and oxygen and ethanesal. It is, of course, familiar to all anæsthetists that many persons suffering from respiratory troubles can be safely anæsthetized with gas and oxygen to which a few breaths of ether are occasionally added. Used in this way no doubt ethanesal is equally successful. That, however, does not justify us in supposing that ethanesal, any more than ether, would of itself be a satisfactory agent to use as the main anæsthetic on persons with severe respiratory disorder. For further details on ethanesal the reader is referred to Mr. Hewer's original article (*Lancet*, June 4, 1921).

[1] *Proc. Roy. Soc. Med.* (Anæsthetic Section), Vol. 14, No. 10, August, 1921.

CHAPTER X

ADMINISTRATION OF NITROUS OXIDE

A. For Short and Dental Operations

Nitrous oxide may be given by itself, or with air, or with oxygen. Its use as a preliminary to other anæsthetics will be dealt with in another chapter. It may also be used in combination with ethyl chloride, and has been given with a weak chloroform vapour [1] and with paraldehyde.[2]

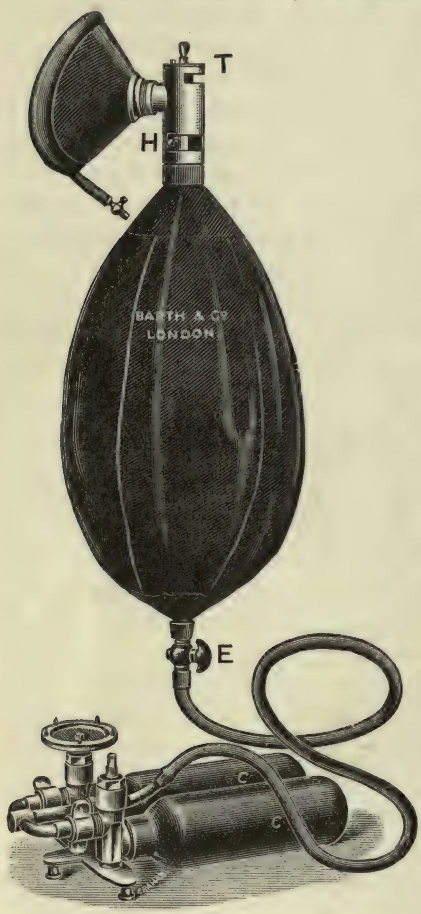


Fig. 20.

We have now to describe the use of nitrous oxide when it is the sole anæsthetic employed—firstly alone, later as it is employed with air or with oxygen. The apparatus necessary when the gas is used alone includes metal cylinders to contain the liquefied gas under pressure, a valve the working of which by a foot-key releases the gas, a tube to convey the gas to a bag from which it is released through a valve to the face-piece, from which it is inhaled. The cylinders are made of iron and of steel. For private practice, where portability is of moment, those which yield 50 and 25 gallons of the gas (15 and $7\frac{1}{2}$ ounces of liquefied nitrous oxide) are more convenient than those yielding 100 gallons, which are

[1] *Lancet*, March 16, 1918, p. 417.
[2] *Proc. Roy. Soc. Med.* (Anæsthetic Section), January, 1922, Vol. 15, No. 3.

best in hospital work. The sound that a full cylinder gives when struck with a metal object distinguishes it from the lighter note of an empty cylinder, but the only safe way to be sure of the contents of a cylinder is to weigh it and see that the weight corresponds with the stated full weight on the label. Two cylinders are to be used coupled together. By continuing the use of one until it is empty and then noting this on the label the anæsthetist saves himself the risk of being left suddenly with two empty cylinders, as may happen if he dodges about, indiscriminately using first one and then the other. As soon as a cylinder is empty it is replaced on the stand by a full one, the original sister cylinder being now put into use. The author has used the side-valve cylinders made by Barth & Co. (Fig. 20) for many years and has found them very satisfactory. The valves do not invariably work with equal ease. If there is any difficulty in starting a valve with the foot-key it will always be found that the difficulty is easily surmounted by using the leverage of a spanner. Care must be taken to turn the valve completely off when the administration is finished. If this is not done gas will leak away and a disappointment greet the anæsthetist when he next uses the cylinder. All the rubber parts of the apparatus must be kept dry and should hang in a warmish place when not in use. If allowed to get stiff and cold, as may happen if they are not employed for a day or two, they soon perish. It helps in the preservation of the rubber parts to dust them with French chalk now and then. Rubber tubing used with gas cylinders should have stout walls so that it does not kink easily. Red is generally better than black rubber for this tubing. The lumen should be about one-quarter of an inch and the thickness of the rubber about one-eighth. The bag is made of much thinner indiarubber and is the more easily damaged. Care must be taken that it is not laid down on the foot-key, the spikes of which will easily tear it. The bag must be kept scrupulously dry, and when, as often happens, ether and chloroform are poured out in its neighbourhood, no drops must be allowed to fall upon the rubber. The bags commonly provided hold about 2 gallons of gas. Between the bag and the face-piece is a metal valved stopcock (Fig. 20). This has a tap which permits of the bag being cut off from the face-piece or continuous with it. The two thin rubber valves contained in the stopcock permit of inspiration from the bag and out into the air, or of to and fro breathing either of gas or of air, according to the way the taps are arranged. The advantage gained by the presence of valves is that in the early stages of induction gas can be inspired without air, and thus the lungs can be well emptied of air and a good concentration of nitrous oxide obtained. Without

such a provision the gas would be too freely diluted with air for narcosis to be obtained quickly. Moreover, breaths of air could not conveniently be admitted and to and fro breathing could not be available. This to and fro breathing (re-breathing) of nitrous oxide is useful if the gas supply should fall short or at the close of an administration for securing a long anæsthesia. Re-breathing, however, should not be used as a routine measure unless the bag can be washed out after each administration. It entails, of course, the contamination of the bag with the patient's expirations, and this must be effectually cleansed before the same bag is used for the next subject. The valved stopcock figured (Fig. 20) is that devised by Hewitt. By its use both air and nitrous oxide can separately be breathed either through valves or backwards and forwards. The valved stopcock has two slots cut out of its circumference, an upper and a lower, and two inner cylinders revolve inside the outer casing. The upper inner cylinder is worked by the tap at the far end of the stopcock and the lower by the tap nearest the bag. The upper cylinder carries the inspiratory and expiratory valves. The lower has a slot in its walls. With the taps arranged as in Fig. 20, air is breathed in at the opening freed by H and out at T. If H is turned, then nitrous oxide is inhaled and expirations still escape at T. If T is also turned, nitrous oxide is breathed to and fro. If T is left turned on and H is now turned off again, air is re-breathed. It will be seen that a breath of air can easily be admitted in the course of administration by turning H off for a breath. The face-piece is made of stout gutta-percha and has a distensible rim of rubber with a tap. The rim can thus be made more or less tense, as best fits the face. When it is blown up to the required tightness the little tap is turned off and the rim keeps its tension. The best results accrue when the face-piece is not too stiff, but has an amount of pliability that allows it to fit the face accurately. A drop or two of pleasant scent may be used with advantage on the inside of the face-piece to overcome the rubbery smell. Before using the apparatus always make sure—(1) that the cylinders contain plenty of gas; (2) that all valves are working smoothly; (3) that there is no kinking of tubing or sticking together of parts of the bag. When there have been many administrations running, the rubber valves in the stopcock may be moistened from the patient's breath and may stick or get curled up. Their condition must be corrected or they must be replaced by new ones. Before beginning an administration send a little gas through the bag so as to drive out all air. Then fill the bag about two-thirds full, arrange the taps as in Fig. 20, and all is ready.

The Administration of Nitrous Oxide for Short Dental Operations

In addition to the apparatus described above the anæsthetist must be provided with a set of dental mouth props of various sizes and shapes to suit any kind of mouth and arrangement of teeth. The form of prop shown in Fig. 21 is in every way suitable. It is made in sizes from one small enough to be easily accommodated by children to that which will suffice for the widest gape, and it is easily cleaned and sterilized. When a tooth from each side of the jaw is to be removed some operators prefer a narrow prop in the middle line so that the one prop answers while either side is being operated on. Otherwise, when both sides of the mouth are to be dealt with, it is best to insert the prop on the right side. When anæsthesia is obtained the dentist operates on the left, and when he has finished there the anæsthetist inserts

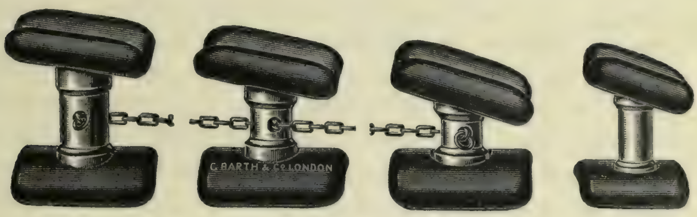


FIG. 21.

a Mason's gag on that side and flicks out the prop from the right side, where the dentist then finishes his operation. This arrangement enables the anæsthetist to keep out of the operator's way better than if the right side is dealt with first.

The bladder should be emptied before taking gas, and it is better that the last feed should be at least four hours earlier. The collars of men and the corsets of women should be loosened if they are tight. An ordinary short extraction of one or of a few easily removed teeth is carried out as follows. The patient sits upright in the chair, his feet resting on the ground or on the foot-rest, the legs not crossed. The hands are on the lap, the fingers of the two hands interlaced. The head is against the rest, neither stretched back nor bent forward. Most people, unless corrected, think it right to stretch the neck and tilt the chin up. If the administration is carried out in this position, gagging is likely to occur from inability to swallow and stertor will arise prematurely, with consequent brief anæsthesia. The anæsthetist stands behind the patient, the gas cylinders handy for his left or right foot, as he prefers. The dentist stands on the right. The apparatus having been tested beforehand and found to work

well and silently, a suitable prop is now inserted between the teeth, the size of the prop and the place in which it is put depending on the position of the tooth to be extracted and the ability to open the mouth. The anæsthetist with his left hand now applies the face-piece firmly but gently to the patient's face in such a way that the narrow end fits closely against the bridge of the nose and the broad end rests against the chin. The administrator's left hand grasps the face-piece so as to control its pressure on the face, and his little finger supports the chin, keeping it well into the face-piece. The object is to hold the mask to the face in such a way that there is no air leakage at all round the rim, and at the same time the chin is not pressed down and no uncomfortable weight is brought against the face. The fingers of the right hand may be employed to secure the fitting of the narrow end of the face-piece to the bridge of the nose, as it is here that leakage most easily occurs. The patient is now breathing air in and out of the mouth, the sound of the expiratory valve showing that it is working rightly. With the right hand the anæsthetist now turns the tap (H), admitting gas to the face-piece, the expiratory valve remaining open. Nitrous oxide alone is now breathed in from the bag, the expirations escaping into the air. With his foot on the foot-key the anæsthetist must turn this and allow gas to enter the bag from the cylinders continuously, to replace that which is inhaled and prevent the bag from being emptied. The key is turned by pressing the sole of the foot firmly on it and sharply rotating the knee outwards. The respiration becomes deeper and quicker, the face flushes and grows dusky, the eyelids twitch at first and then close as a rule. There may be one or two swallowing movements to interrupt the breathing, but after ten to twenty or thirty breaths, according to the subject, the respiration becomes jerky with a characteristic guttural sound (stertor), the conjunctival reflex is gone, the pupils are dilated, the face and lips cyanosed, and anæsthesia is present. The face-piece is removed and rapidly put aside while the anæsthetist steadies the head and the extraction is carried out. Sometimes *jactitations*, due to clonic contractions of the arms or legs, or tonic contraction of muscles of the back, causing opisthotonos, arise, and these must lead at once to removal of the face-piece without waiting for stertor. Again, it occasionally happens that, without any of these grosser anoxæmic symptoms, the patient's face becomes pale and the breathing shallow. The administration must at once cease, and it will generally be found that anæsthesia is present enough to allow the extraction.

The symptoms above described are not invariable. Occasionally the eyes open, and occasionally the pupils do not dilate or the conjunctival reflex disappear. Indeed, the eyelids sometimes

retain their tone to an extent making them hard to open. The corneal reflex is very rarely abolished by a simple nitrous oxide inhalation. The muscles usually, but not always, become flaccid before the contractions due to clonic or tetanic excitement occur. Micturition rarely, and defecation still more rarely, happens unless the bladder and bowels are too loaded at the time of administration. The characteristic " stertor " of nitrous oxide inhalation is attributed to irregular and spasmodic elevation of the larynx. Sometimes this feature of respiration is not produced, but instead there is a loud, less jerky snoring sound more comparable to the stertor commonly produced by closed ether administrations. Again, there may be a "false stertor," a gentle snore which does not betoken full anæsthesia. If this is taken to indicate the moment for operation, although pain may not be felt, the patient will be aware of what is done. Sometimes irregularity in the breathing without the typical stertor is due to clonic contraction of the thoracic and abdominal muscles. Superficial reflexes, generally speaking, are abolished, but deep ones retained. The general rule, that the longer an anæsthetic is inhaled the longer is the anæsthesia produced, holds good with nitrous oxide, and a longer narcosis commonly follows in patients who do not quickly show the culminating anoxæmic symptoms. Similarly the longer the elimination of the drug takes the longer is the anæsthesia. This has a practical bearing in the case of nitrous oxide, for operations on the lower teeth, when the operator's work by depression of the jaw interferes with breathing and so delays elimination, can always be counted on to receive a longer available anæsthesia than extractions from the upper jaw.

The anæsthesia thus obtained from nitrous oxide alone is of very short duration. The average available time, during which there is complete unconsciousness, is thirty seconds, and this may be followed by a brief period of analgesia, during which pain will not be felt, but the patient will be aware of what is happening. The average time taken to produce full anæsthesia is little under a minute. The anæsthesia is cut short, we see, by the advent of stertor or convulsive movements, anoxæmic or asphyxial symptoms due to the irrespirable nature of pure nitrous oxide. The gas is to be used alone in this way only for the shortest of extractions. If there is any doubt as to the ease with which the tooth or teeth will be removed methods giving longer time must be employed. Moreover, there are many patients in whom it is not desirable to bring about the asphyxial state essential for anæsthesia when this is obtained by pure nitrous oxide alone. The sensations also associated with anæsthesia obtained in this

way may be uncomfortably suffocative. On the other hand, after-effects are entirely absent. On the whole, we may say that the procedures about to be described should almost always be preferred to the administration of unmitigated nitrous oxide, and in any case this must be restricted to very short operations on perfectly sound and healthy adult subjects. Children under pure nitrous oxide very quickly become convulsive and give an exceedingly short period of anæsthesia. The same is true of anæmic persons. The latter may become anæsthetic with very few breaths of pure nitrous oxide. Hewitt relates the case of a patient suffering from pernicious anæmia in whom the muscular phenomena of full nitrous oxide anæsthesia appeared during the third breath.[1] There is, of course, much difference in the amounts required for different types of subject. The muscular and full-coloured people take longer to become narcotic. In them also the colour change is most marked, the face becoming cyanotic by the time that anæsthesia is reached. The average number of breaths required for deep anæsthesia is about thirty. Hewitt found the figure to be 29·2 in sixty consecutive administrations.[2]

The *stages of narcosis* cannot be discerned under nitrous oxide, unconsciousness and anæsthesia coming on too quickly. Some kind of division of the effects produced may, however, be made in accordance with the subjective sensations and the visible phenomena. The first sensation produced is generally a pleasant one of warmth and tingling. Ideas rush through the head and usually centre round the notion that the administrator cannot realise all that the patient is experiencing. While this wonder "whether it is really all right" is in the patient's mind he feels a growing fulness of the head, and just as this is about to become extreme, unconsciousness envelops him. Often these sensations are allied with the feeling that the patient is travelling rapidly in a train or a motor car. Nowadays patients not infrequently say that they were in an aeroplane. These sensations are presumably associated with the vigorous breathing and the heightened circulation that accompany the inhalation of nitrous oxide. The pulse grows more forcible. Unconsciousness is generally present in about twenty to thirty seconds after the first breath of the gas. Reflex effects are almost sure to follow if operation is performed directly consciousness is gone and before deep narcosis is reached. The conjunctival reflex is at this period often still active and the pupil widely dilated. A cry or movement of the limbs or both will accompany an extraction if performed just now. The patient will be unaware of this, although

[1] *Loc cit.*, p. 294.
[2] *Ibid.*, p. 293.

in some cases he will regain consciousness while he is still crying out, and will then, of course, know that he has made a noise. He will say that he heard his own scream, but could not stop it, and that he felt no pain. Although no pain may be felt, it is undesirable to operate during this stage of light narcosis. Many persons will experience vague sensations of terror, although they have felt no actual pain, and the memory of these sensations will intimidate them on future occasions. The same thing occurs when an operation started in full anæsthesia continues when the patient has again come round to the extent of being only in light narcosis. Dreams of a terrifying nature may then trouble the patient and be remembered afterwards. Occasionally after such an experience the patient will find his ordinary sleep troubled for a long time. Just as he is dropping off each night he will re-experience the terrors which attacked him under nitrous oxide at a time when presumably his mental condition was exactly comparable with that which it reaches immediately before normal sleep. The dreams of light nitrous oxide narcosis are sometimes of an erotic nature, and this may become obvious in the character of the muscular movements evoked. It is because of the occurrence of such dreams and of the persisting impression that they may leave on the patient's mind that it is unwise ever to give nitrous oxide except in the presence of a third party. For these dreams have often led women to accusations of misbehaviour. The great majority of those who take nitrous oxide are unable to recall any dream at all when they come round. Very often they are aware that they have had a dream and at the moment of awaking desire to communicate it. The next moment they are unable to do so, often greatly to their annoyance. A famous *raconteur* woke up after "gas" and told me that he had dreamed the best story he ever heard. When he wanted to tell it great was his disgust at not being able to recall a word. Some persons repeat the same dream on each occasion that they go under nitrous oxide. Unfortunately in my experience when this is the case the dream is generally not an agreeable one. Dudley Buxton [1] says that "dreams, common with every kind of general anæsthetic, are not always remembered. Many such dreams probably arise as the patient is regaining consciousness; if of a disagreeable character, they are usually the result of some perception of pain due to the concluding steps of an operation or of 'after-pain.' This is a common type with nitrous oxide inhalation." This author distinguishes types of dream. He mentions pleasurable dreams and "horrors" which leave an indelible impress on the mind and may be recalled at wide intervals

[1] *Lancet*, Jan. 1, 1921, p. 9.

of time under subsequent narcoses. With regard to erotic dreams he remarks: "The patient is left somewhat exhausted and, in the case of women, obviously disturbed if the anæsthesia has been brief and recollection of the erotic sensation is dimly present on recovery." This applies fairly frequently in my experience to nitrous oxide and to no other anæsthetic. Buxton concludes from the dreams of anæsthesia, especially those which are repeated in identical detail at wide intervals of time, that we deal in anæsthesia not only with ordinary consciousness as tested by motor reflexes, but with the subconscious hidden mind.

The *after-effects* of an inhalation of pure nitrous oxide are generally negligible. Slight headache or dizziness may follow for a short time. Rapid return to complete consciousness is the rule. *Emotional states* may follow in those predisposed to disturbance of that kind. Sometimes there is weeping without any corresponding emotion, and the patient is annoyed at her inability to prevent the tears. Occasionally a prolonged sleepiness ensues, and this is rather less uncommon with children than with adults. On the other hand, inability to sleep for some nights after has followed an administration. Occasionally there is a feeling of faintness, and very rarely there is brief vomiting. This is more likely to occur in the presence of swallowed blood. Hemiplegia and insanity have been recorded, but are to be regarded as extreme rarities. The venous congestion caused by pushing an administration of nitrous oxide would favour the rupture of vessels within the head, and *retinal hæmorrhage* has actually been recorded.[1]

Dangers due to an inhalation of pure nitrous oxide are, in the case of healthy subjects, limited to those of obstructive asphyxia. If the administration is pushed beyond the point at which those symptoms arise which have been described as showing that the anæsthetic must be withdrawn, then death from asphyxia may be brought about. The onset of danger would be obvious from the congestion and altered colour of the face, from the jerky spasmodic breathing, the dilated pupils, sweating brow, and convulsive limbs. If with the patient in this condition no air is admitted or the face-piece removed, then the heart may fail secondarily to the arrested breathing. Although it is true that a healthy subject could not be brought to this pass without his condition being very obvious, yet it must be remembered that in some people obstructed breathing arises much more easily than in others under nitrous oxide. All persons with high, narrow palate, such as we find in those who have suffered from post-nasal obstruction in childhood, and those with narrow, imperfect nasal

[1] Hewitt, *loc. cit.*, p. 304.

passages, easily become congested and imperfectly aerated when taking "gas." The tongue in such people is swollen and often spasmodically retracted. The subjects of tonsils and adenoids in like manner readily get an occluded airway. Among those who cannot be described as healthy subjects, the patients suffering from acute cellulitis of the neck may experience such a rapid diminution in the lumen of the upper air passages from inhalation of nitrous oxide that the gas is never to be administered to them (see p. 287).

An *open method* of giving nitrous oxide was devised by Flux [1] in order to accommodate those who are frightened or inconvenienced by a closely fitting face-piece. He used an open inhaler into the upper part of which nitrous oxide was allowed to flow during inspiration, the weight of the gas leading it to the patient. The method is very extravagant of gas, and its advantages can really be obtained by judiciously graduating the application of an ordinary face-piece.

Administration of Nitrous Oxide with Air

Better results than those obtained from nitrous oxide alone may be gained by combining it with air. In this way a longer anæsthesia may be obtained for dental and oral cases in which the mask must be removed to permit of operation ; while in other surgical cases the judicious use of air renders the anæsthesia of nitrous oxide available for many minutes. The method is to be used, however, only for cases in which absolute immobility and relaxation of muscles is not essential. The type of anæsthesia obtained cannot compare favourably with that given by ether, chloroform, or gas and oxygen. Yet the proper use of gas and air is of much practical service, since it provides with comparatively simple apparatus an anæsthesia sufficient for many minor surgical proceedings. The clinical researches of Hewitt showed that anæsthesia can be obtained with as high a proportion as 30 per cent. of air to 70 of nitrous oxide. He found, however, that the best results followed on the use of mixtures containing 14 to 18 per cent. air in the case of men and 18 to 22 per cent. for women and children. As commonly employed the method does not register in any way the percentage of air used, but relies upon the symptoms evoked for hitting off about the correct proportions. The apparatus used is the same as that for giving nitrous oxide alone. The supply of air is obtained generally in one of two ways. In one, which gives the best results practically, breaths of air are admitted when necessary, and are alternated with breaths of

[1] *Trans. Soc. Anæsthetists* (London), Vol. 2, p. 140.

nitrous oxide. In the other small amounts of air are admitted throughout concurrently with the gas. To conduct the administration by the first method patient and apparatus are arranged as described for nitrous oxide alone and the administration is started in exactly the same way as there described. After ten breaths, however, or sooner if there is irregularity in the breathing, a breath of air is admitted by turning off the tap which controls the exit of gas from the bag. Then gas is admitted again, and after five breaths another one of air is given, and so on, alternating air and nitrous oxide till signs of anæsthesia are present. Then in the case of dental operations the face-piece is removed and the operation performed. In the case of operations not on the face the inhalation is continued while the operation goes on, air being admitted more and more frequently, till often the administration consists of one breath of air to two or three of nitrous oxide. The beginning of jactitation, of cyanosis of the face, or of loud stertor indicates the necessity for more liberal air supply. Frequently it is advisable to lift the face-piece off the face entirely for a few breaths, resuming before consciousness returns. The other method consists in keeping the tap (H) slightly open throughout the administration, so that a small amount of air enters with every inspiration. When more air is needed the tap is opened still further; when less it is closed. The anæsthesia obtainable from nitrous oxide and air used in these ways is often well suited to such operations as opening abscesses, removing small superficial cysts and tumours, amputating fingers and toes, and the performance of painful dressings. After-effects are usually of the slightest, and in healthy subjects the procedure is a singularly safe one. When applied to dental surgery an available anæsthesia is obtained considerably longer than that due to nitrous oxide alone. Moreover, the anæsthesia is less violently stertorous. Indeed, the characteristic stertor of nitrous oxide and the regular jactitations must not be waited for. If air has been given in due proportion anæsthesia is generally present before these symptoms arise and is heralded by irregularity of the breathing, absent conjunctival reflex, and fixity of the eyeballs. The first extensive movement of the eye is generally a good sign that consciousness is returning, and is a useful sequel to watch for during dental operations. When it occurs the operator is warned to stop.

For *further prolongation of nitrous oxide anæsthesia in dental and oral cases* the gas may be administered through the nose, thus allowing its inhalation during the performance of the operation within the mouth. Coxon [1] used a tube within the mouth

[1] *Trans. Soc. Anæsthetists,* Vol. 1, p. 123.

through which to continue the administration of gas during dental operations. The nasal methods give better results. Theoretically objections may be raised against this practice on the score that respiration during anæsthesia is not efficiently carried out along nasal channels. In practice, however, very good results are obtained, and "nasal gas" allows the dentist to operate without any hurry. At the same time the method must be regarded as less safe than oral administration, and should not be used when there is any doubt of the efficiency of the patient's heart or lungs. Although the anæsthesia is not so uniform as that obtained by oral inhalation, yet in the vast majority of cases a perfectly satisfactory condition can be obtained and can be maintained for several, even for many, minutes. The operator is thus not handicapped by the knowledge that the anæsthesia may finish before he has. A number of extractions may be effected at one sitting which would otherwise need several separate administrations of nitrous oxide or one of ether. Although it may often be bad policy to use "nasal gas" in order to extract a large number of teeth, yet the method is of great value even when there are only a few teeth to be removed, but the dentist cannot be certain that they will come out easily or within the time available from an oral administration. Cyanosis arises easily during nasal inhalation of nitrous oxide. A state of analgesia rather than anæsthesia is often maintained for a considerable time. This is especially apt to occur when the patient breathes through the

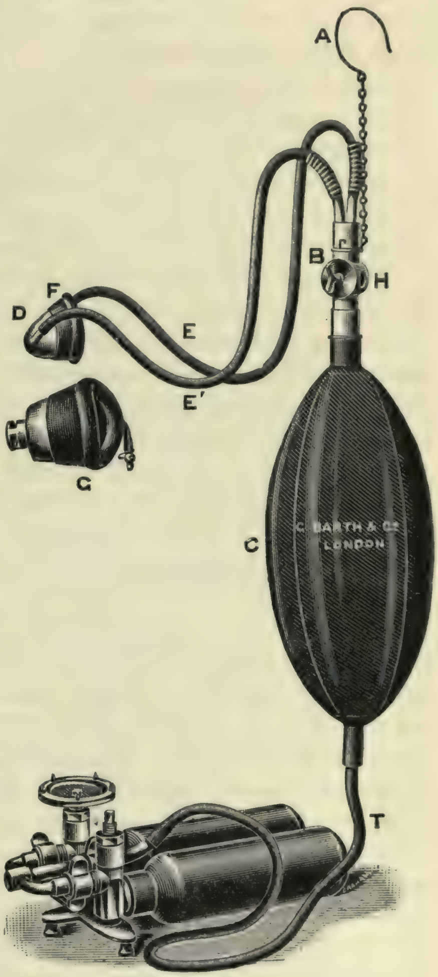


FIG. 22.

mouth as well as through the nose during the operation. Many persons are unable to breathe freely through the nose. The best results cannot be obtained with them, though much help is got by delivering the gas under some pressure. Success also depends largely on the soft palate keeping forward. Sufficient pressure of gas must be kept up to secure this.

Various forms of apparatus have been designed for nasal administration of gas. Harvey Hilliard delivered the gas through a catheter passed through a nostril. Good results can be achieved by using the apparatus already described with the alteration that the mount of the stopcock, instead of fitting on to the face-piece, fits on to a short metal tube connected with the rubber tubes which lead to a nasal cap. The cap and tubes are those devised by Paterson (Fig. 22). The cap is of aluminium with a rubber rim. The expiratory valve being closed and the bag kept fairly distended with nitrous oxide, this passes straight to the nose-piece. During induction a mouth-cover with an expiratory valve may be used to prevent all oral inspiration (G, Fig. 22). In the apparatus devised by Coleman [1] and that by Trewby [2] nitrous oxide can be given both by the mouth and the nose during induction, the mouth route being switched off later. Breaths of air can also be admitted without raising the nose-piece. Both these forms of apparatus provide spring pressure upon the gas-bag. A nasal administration of nitrous oxide and air is carried out as follows. The patient, having cleared his nose, sits and the mouth-prop is inserted as described for oral inhalation. He is asked to "sniff up through the nose and breathe out of the mouth," and the nose-piece is carefully fitted so that no air leakage occurs round its edge. The gas-bag, distended, hangs by a hook to the back of the dental chair. Holding the nose-piece firmly in position with his right hand, the anæsthetist turns on the nitrous oxide from the bag by closing the stopcock (Fig. 22). The expiratory valve is closed, and the patient now breathes in nitrous oxide. If he breathes in through the mouth at all the expiratory mouth-piece is held firmly to the face below the nose-piece, rendering oral inspiration impossible. The patient then either breathes nitrous oxide to and fro through the nose or inhales the gas through the nose and expires through the mouth. Anæsthesia usually comes on quietly. Breaths of air are given as required by turning off the stopcock (B) or by raising the nose-piece during an inspiration. No great amount of cyanosis is to be permitted, a breath of air generally being needed about every third breath after unconsciousness. Violent convulsive move-

[1] Dudley Buxton's "Anæsthetics," 1920, p. 92.
[2] *Proc. Royal Soc. Med.* (London, 1911), Vol. 4, pt. I., p. 12.

ments, if allowed, make it very difficult to keep the apparatus in position. During the performance of the extractions the anæsthetist, armed with a sterile sponge in his left hand, takes care that no blood enters the pharynx. When two sides of the mouth are to be operated on, as soon as the dentist has finished with the first the sponge is firmly pressed in there and left while the other extractions take place. Any oral inspiration during the extraction, causing the anæsthesia to be too light through over-dilution of the gas with air, is curtailed by blocking the mouth to some extent with an additional sponge. The advent of anæsthesia is not made evident, of course, by any " stertor " like that heard with oral inhalation of nitrous oxide. An expiratory sound, however, probably due to flapping of the soft palate, is generally to be heard when full unconsciousness is reached. Since the gas will continue to be inhaled during operation, there is no necessity to deepen the narcosis beyond this point. It can simply be kept at this level while the operation proceeds. The anæsthetist should aim, in fact, at keeping throughout an anæsthesia less than that which he attains with oral inhalation when at its climax. If he keeps a deeper narcosis than this during the comparatively long time of a nasal administration he may over-dose his patient and have to contend with all the inconveniences of convulsive movements, opisthotonos, and jactitation as well as incurring some asphyxial risk.

Nitrous Oxide with Oxygen.—The advantages gained by using air with nitrous oxide are improved upon by the employment of oxygen. Air is required only for the oxygen which it provides, and by using this gas itself greater accuracy is possible, the nitrous oxide is rendered respirable for a longer time, and so a smoother and a longer available anæsthesia is obtained. The only drawback is that slightly more complicated apparatus is essential. For short operations and for dental work the apparatus devised by Hewitt is unsurpassed. For long operations and major surgery generally we shall see that more recent inventions have rendered possible results that can hardly be achieved with Hewitt's apparatus. We have seen that the use of air, although a great improvement on the use of nitrous oxide alone, does not allow us to abolish entirely the asphyxial symptoms of full nitrous oxide narcosis. That is because if enough air is used to keep cyanosis, stertor, and jactitation entirely absent, then enough nitrous oxide cannot be given with it to ensure full anæsthesia. Replacing the air, only one-fifth of which is oxygen, by oxygen itself, it is plain that we can use much larger amounts of nitrous oxide and yet retain the same proportion of oxygen. In this way we can use enough nitrous oxide to ensure anæsthesia and

at the same time enough oxygen to banish asphyxia. It will be remembered that Paul Bert proved the possibility of procuring anæsthesia by nitrous oxide and oxygen, but believed that increased atmospheric pressure was essential. Before him Andrews, of Chicago, in 1868 had recorded anæsthesia by nitrous oxide and oxygen. It was chiefly the work of Hewitt, however, which showed that no increased pressure was necessary and which placed the clinical use of nitrous oxide and oxygen on a sound footing. Many workers have since then improved upon the apparatus that Hewitt designed and have introduced new and valuable principles. Smooth, continuous flow of gases, visible and controlled by fine adjustment valves, vertical cylinders, re-breathing and warming of gases, are comparatively recent innovations with which we associate the names of Cotton, Teter, Gatch, Connell, Boothby and Gwathmey in America. In this country Geoffrey Marshall, Boyle and Shipway have devised apparatus embodying the principles and rivalling the products of their American *confrères*. The exact position of long administration of nitrous oxide and oxygen as regards safety cannot yet be definitely stated. It is clear that the absolute safety claimed for this anæsthetic for short operations—and claimed with justice, as time has proved—cannot be counted on in long administrations. The matter is further considered on p. 390. Experimenting with various percentages of oxygen and nitrous oxide, Hewitt [1] found that the duration of inhalation necessary was longer the more oxygen used. With 3 per cent. oxygen, for instance, the average inhalation period for anæsthesia was 96·6 seconds, with 20 per cent. oxygen it was 223·5 seconds. Again, the longer the inhalation the longer he found was the available anæsthesia obtained. Moreover, this was longer than that obtained by mixtures of air and nitrous oxide. The best results attended a mixture of 7 per cent. oxygen with 93 per cent. nitrous oxide, and Hewitt concluded that for men mixtures of 5 to 7 per cent. and for women and children those of 7 to 9 per cent. were generally to be employed. The anoxæmic symptoms of pure nitrous oxide are the more completely abolished the higher the percentage of oxygen used. Even with 5 per cent. oxygen the jerky stertor of nitrous oxide is replaced by a regular snoring sound. With higher percentages this sound is diminished, and with 20 per cent. oxygen it is abolished. Reflex and excitement movements are uncommon with small percentages of oxygen, but may become inconvenient with 10 per cent. or more.

Nitrous Oxide and Oxygen in Dental and Minor Surgery.—Hewitt's apparatus (Fig. 23), which answers well all demands in

[1] *Loc. cit.*, pp. 312 *et seq.*

these cases, consists of a double bag connected with a metal regulating stopcock and mixing chamber, which fits on to the face-piece. The bag is connected by a V-piece with nitrous oxide and oxygen cylinders by rubber tubes one inside the other. The inner conveys oxygen, the outer nitrous oxide. From the regulating stopcock emerge two metal tubes, each containing a

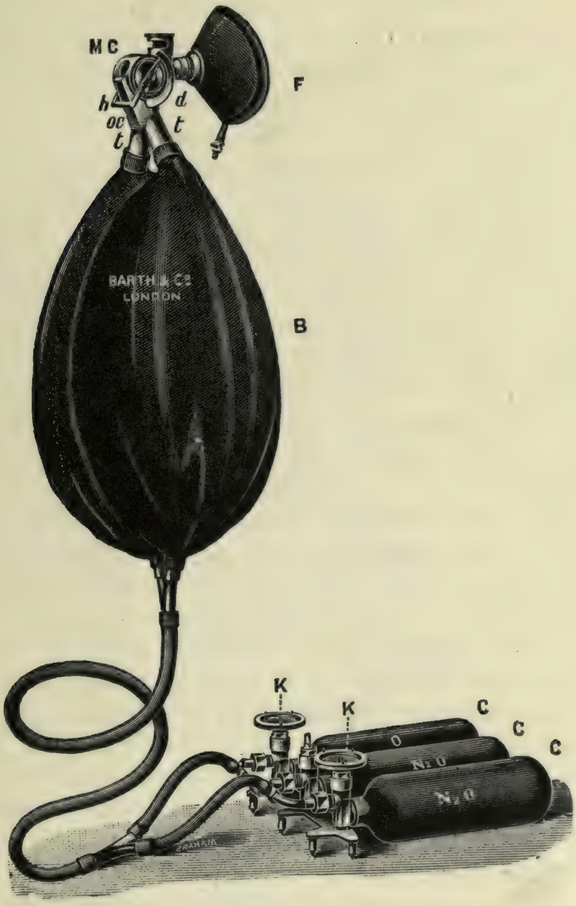


FIG. 23.

removable inspiratory valve. These tubes connect with the two mouths of the double bag, receiving respectively oxygen and nitrous oxide. After passing the inspiratory valve oxygen reaches the mixing chamber through a number of openings which are thrown open by a handle which works an indicator. On the dial the anæsthetist reads the figure representing the oxygen which he is admitting. Nitrous oxide, after passing the inspiratory valve, reaches the mixing chamber through the large opening.

From the mixing chamber the gases are inspired into the face-piece through a main inspiratory valve, and an expiratory valve at the end of the stopcock allows expirations to escape. The handle of the stopcock, by the position to which it is pushed, which is marked on the dial, allows air or nitrous oxide alone, or nitrous oxide and oxygen in proportions from about 1 to 20 per cent., to be inspired. No re-breathing is possible. Hewitt pointed out in his description of the apparatus that the precise percentage of oxygen going through the holes into the mixing chamber depended on various circumstances and that the figures on the dial do not represent accurate percentages of oxygen.

In *using the apparatus* it is important first of all to make sure that all valves are in working order and that the supply of gases in the cylinders is adequate. The two divisions of the bag are then half filled with their respective gases. A face-piece is then chosen which fits the patient accurately and comfortably. Posture, mouth-prop and other details are attended to as described in connection with nitrous oxide, but the preparation of the patient, except for the shortest operations, should be the same as before the administration of ether and chloroform. Holding the face-piece firmly against the face with the left hand, just as in the case of nitrous oxide, the anæsthetist judges by the sound that air is being breathed freely through the open stopcock and then turns the indicator to the mark "2." The patient now inhales about 2 per cent. of oxygen with 98 nitrous oxide and exhales into the air. After a few breaths the indicator is further advanced to "3," "4," "5," and after about a minute it may be at "7." The rapidity with which it is advanced depends on the absence of all excitement. If there is phonation or excited movement the amount of oxygen is at once reduced. All the time the administrator has his foot on the foot-key and is letting nitrous oxide flow into the bag, so that the two sides of this are kept equally distended, as they were before administration began. For dental cases the requisite anæsthesia is reached on an average after about one and a half to one and three-quarter minutes' inhalation. This gives an available anæsthesia of about forty to fifty seconds. The period of inhalation and the resulting anæsthesia, it is seen, are considerably longer than with nitrous oxide, even when air is combined with it.

The *effects produced* are at first very similar to those accompanying nitrous oxide inhalation, but the suffocative feeling that often troubles patients with the gas alone is now absent. The face does not change colour to the extent previously observed with nitrous oxide, and the breathing does not become quickened or vigorous to the same degree. When anæsthesia is established

the respiration is generally accompanied by a slight snore, and the colour of the face is commonly either rather paler than normal or slightly flushed. The pulse retains its normal force. The *pupils* are generally only moderately dilated and the conjunctival reflex almost always absent. Spasm of the eyelids is often present during the first half-minute or so of the inhalation. The globes are usually fixed when anæsthesia is reached ; occasionally they show slight oscillatory movement. The muscles of the limbs are generally flaccid.

When employed for short operations not involving the face the amounts of oxygen admitted can generally be progressively increased with advantage. In feeble and anæmic subjects it is often advisable in the course of the operation to give a few breaths of undiluted air, raising the face-piece for the purpose. The more plethoric, muscular or nervous the patient the less freely can oxygen be used with the gas. Thus the typical "difficult subject" is not a good person on whom to use "gas and oxygen," unless the operator is satisfied with a bodily condition that is far from being absolutely quiet. Stertor and convulsive movements readily arise in alcoholics and the other difficult types of person, and reflex movements are almost sure to appear if the operation involves any sensitive area. The anæsthetic will be perfectly satisfactory from the patient's point of view, leaving him quite comfortable on recovery and oblivious of pain during the operation, but it will leave much to be desired from the point of view of the operator. In weak persons, children, and those who are reduced by illness, on the other hand, gas and oxygen given in this way provide a most satisfactory anæsthesia for most operations taking about a quarter of an hour. Rectal operations should generally not be attempted with this anæsthetic. For long proceedings it is extremely extravagant in gas and laborious for the anæsthetist, whose foot is never free. Moreover, the freezing that occurs at the valve of the nitrous oxide cylinder interferes with uniform flow of gas in the course of a long operation. For these and for other reasons the forms of apparatus described later are to be preferred to Hewitt's for major surgery. Nevertheless, before their invention administrations as long as two hours and a quarter were successfully achieved.[1] The *after-effects* are usually slight after short operations, although not quite so trivial as in the case of nitrous oxide alone. Nausea and slight vomiting are not uncommon. One case of prolonged sleep after a short inhalation of "gas and oxygen" is recorded.[2] After long operations after-effects have occasionally been severe, though

[1] *Trans. Soc. Anæsthetists*, 1902.
[2] *Lancet*, March, 1902.

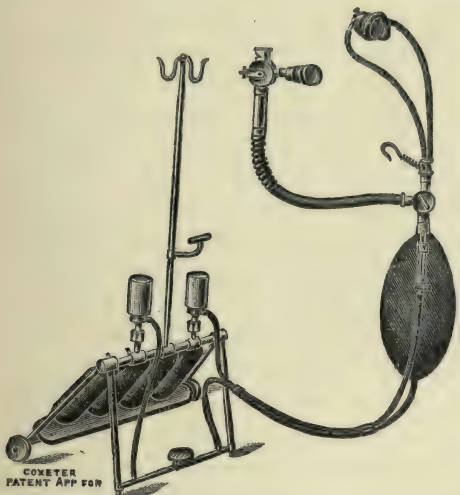
rarely equal to those following an ether administration of the same duration. The *safety* of nitrous oxide and oxygen for short operations is unrivalled. When properly employed the possible asphyxiation, which is the danger to be feared with nitrous oxide alone, is obviated, and it cannot be said that there is any danger at all to be apprehended from the anæsthetic *per se.*

Nasal Administration of Gas and Oxygen.—In order to secure for prolonged dental cases the advantage of using oxygen with nitrous oxide the anæsthetist can avail himself of the modification of Hewitt's apparatus devised by Bellamy Gardner. By introducing an arrangement which permits of re-breathing, through throwing the expiratory valve out of use, and employing the bags devised by Levy, Bellamy Gardner [1] has provided an apparatus with which excellent results are obtained. Levy placed the two bags of Hewitt's apparatus one inside the other instead of side by side. The oxygen bag is within the nitrous oxide. In this way the pressure within the two is equal unless the internal one is distended. The use of the apparatus is thus described by its author: "The apparatus having previously been suspended by a metal hook from the back of the dental chair and the valve chimney taken out and reversed, the nose-piece, held in the anæsthetist's right hand, is carefully adapted over the patient's nose, so that respiration through it is free and comfortable. Nitrous oxide and 6 per cent. of oxygen are then turned on and re-breathing into the bag begins. This can be seen to occur by the rise and fall of the outer bag." If the patient does not breathe through the nose the mouth cover must be used as described with nasal nitrous oxide and air. Generally not more oxygen is needed than is represented by the figure 15 on the dial. With suitable subjects there is scarcely any dental operation that cannot be conveniently performed under the anæsthesia produced in this way. As is always the case where nitrous oxide and oxygen is the anæsthetic, there must, however, be proper selection of subjects. To attempt very numerous extractions or extraction of difficult impacted wisdom teeth from a fat alcoholic patient with gas and oxygen by the nasal route would be to court failure. Long dental operations on difficult subjects are best performed under ether.

It is important in multiple extractions that blood is not allowed to enter the pharynx during the nasal anæsthesia. If it does it may cause retching and swallowing movements. The anæsthetist must use a sponge, as already advised. Similarly when the burr is being used a sponge placed behind the tooth prevents the flying dust from irritating the pharynx. The

[1] "A Manual of Surgical Anæsthesia," p. 106.

anæsthesia produced by nasal gas and oxygen is similar to that which follows oral inhalation of the gases. It is accompanied by a quiet form of respiration, with little change in the colour of the face and a pulse but little quicker and fuller than the normal. In order to maintain this condition during operation oxygen is generally given more freely than during the short oral inhalations. Persons are occasionally encountered with scarcely any or no



Registered Design.
FIG. 24.


FIG. 24A.

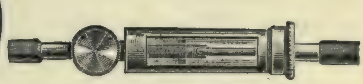


FIG. 24B.

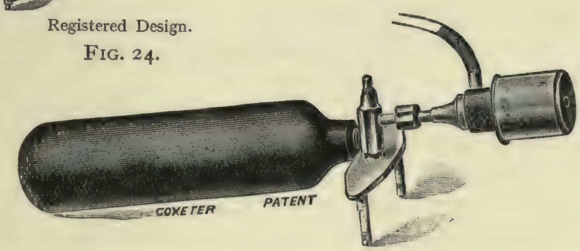


FIG. 24C.

possible nasal respiration. For them, of course, the method must not be attempted.

A semi-automatic apparatus for nasal administration of nitrous oxide with or without oxygen has recently been constructed by Coxeter & Son (Fig. 24). The nose-piece in this apparatus (Fig. 24A) is wide and shallow, thus interfering as little as possible with the operator. The gas is automatically controlled at the cylinder (Fig. 24C), and the oxygen passes through a sight-feed control valve (Fig. 24B).

Nitrous Oxide and Oxygen in Major Surgery

The use of this anæsthetic for extensive operations has increased enormously during recent years. It received an unnatural impulse during the Great War, for then there was an

abnormal proportion of cases in which it was superior to all other anæsthetics. These were cases of operation upon individuals suffering from severe shock, trauma, or exposure. The vast numbers of the wounded afforded anæsthetists in a short time an amount of experience which would require years of ordinary practice. Thus opinion rapidly crystallized, and as regards the proper anæsthetic for patients who had to be operated on when vitality was at a low ebb nitrous oxide and oxygen soon took the first place. By its help a certain number of lives could be saved under desperate conditions, and this number was more than that of the successes attending any other method of anæsthesia. Doubtless this is owing to the fact that nitrous oxide has no toxic effect on the tissues of the body, that it is rapidly got rid of, and that it has no lowering effect on the blood pressure. Furthermore, very many of the operations required in the military hospitals away from the front, both abroad and at home, were those which are very conveniently managed under gas and oxygen. These are operations for bone sinuses, trimming of stumps and the like. The surgery of civil life does not offer nearly so large a field in proportion where " gas and oxygen " is the first anæsthetic. The great success which attended this agent in war surgery has swung the pendulum of favour rather too widely in civil practice also, and at present there is an inclination to overestimate the cases which should be treated with " gas and oxygen " only and to attribute to this combination successes which are due to the use of gas and oxygen in combination with ether. It is, in fact, by combining gas and oxygen with ether and with local anæsthetics that its use can be very widely extended in the severe operations of civil surgery. Here, too, the immunity from after-effects and from shock as compared with the consequences of the same operations performed under ether or chloroform gives the greatest value to the use of gas and oxygen. Even if that anæsthetic is not of itself sufficient, a great deal is gained when it can be made the chief anæsthetic agent instead of leaving this *rôle* to a more toxic anæsthetic. To secure the best results by the use of nitrous oxide and oxygen alone in major surgery very careful selection is necessary. Only some patients and only some operations are well suited by this anæsthetic. The patients must not be of the very muscular, plethoric, or excitable type. Nor are good results easily obtained with those who have narrow, high palates and congested fauces. The operations should not involve the abdomen or rectum. Feeble patients and those who are very ill are suitable subjects. Most operations on the limbs, superficial operations anywhere, minor gynæcological operations, and breast operations, both short and long, give the

best opportunities for nitrous oxide and oxygen alone. In the case of males a preliminary injection of omnopon gr. $\frac{1}{3}$ with atropine gr. $\frac{1}{100}$ or with scopolamine gr. $\frac{1}{100}$ is always advisable. It is preferable, but not so important, with females, and should be omitted with children. The *preparation* of the patient should be the same as that before any other general anæsthetic. This is the best security for comfort afterwards, and also allows for the use of other anæsthetics should they become necessary in the course of the operation.

The *apparatus* [1] for administering the gases should :—

(1) Allow a regular flow of each gas at any rate required, without the necessity for frequent valve manipulation ;
(2) Provide for the addition easily and rapidly of ether, even in high percentage vapour, if necessary ;
(3) Have a face-piece which can be made to fit accurately and be self-retaining ;
(4) Make the flow of the gases visible, so that their proportions can be approximately estimated at a glance ;
(5) Provide for re-breathing.

The simplest form of apparatus with which good results can be obtained by long administrations of nitrous oxide and oxygen consists of the bag and stopcock described for the use of nitrous oxide only connected by a V-piece to cylinders of nitrous oxide and of oxygen. Here we have, of course, no means of measuring the proportions of the gases used, nor of seeing them, and must be guided solely by the colour and other symptoms displayed by the patient. Re-breathing is achieved by closing the expiratory valve. The foot must be kept throughout on the key of the nitrous oxide cylinder, except when it is moved to the oxygen key. In a long case freezing is very apt to occur at the valve of the gas cylinder and interfere with the uniform supply. Moreover, it is not easy to supply oxygen insufficient proportion to keep the patient free from cyanosis, owing to the almost constant employment of the foot on the nitrous oxide foot-key.

The *administration* is carried out as follows :—A small prop is placed horizontally between the bicuspids on one side unless the nasal passages are perfectly unobstructed. The bag is distended to about two-thirds its full extent partly with oxygen and partly with nitrous oxide, the latter representing about two-thirds of the total gases. The face-piece being accurately adapted to the face, with the head slightly raised and turned to one side, the patient breathes air once or twice, the tap (H, Fig. 20) being turned off and the expiratory valve open. Now H is closed, and for a couple of breaths the mixed gases are inspired and the expirations

[1] Gwathmey's "Anæsthesia," p. 162.

allowed to escape. Then close T (Fig. 20) and with the foot run in more nitrous oxide. Re-breathing of nitrous oxide and oxygen is now going on. The chin is being kept well forward by the anæsthetist's left hand, while his right steadies the face-piece in accurate apposition with the face. The breathing increases in depth and frequency. If there is any stertor or twitching of muscles or beginning cyanosis more oxygen is admitted. In about one to two minutes anæsthesia is present, as shown by regular automatic breathing, usually with a slight snoring sound, absent conjunctival reflex, and relaxed limbs. It is well, unless the operation is so situated that a little movement is of no consequence, to delay the incision till anæsthesia has been present for another minute. Then the operation begins and the anæsthetist regulates the gases that he supplies by keeping a careful watch on the patient's breathing and colour. The secret of success is to keep a quiet, unobstructed form of respiration and a colour that is pink or only slightly duller. The longer the operation lasts the more is the oxygen that can be admitted in proportion to the nitrous oxide. Every two or three minutes, moreover, the bag must be allowed to empty itself almost completely by the opening of T. Otherwise the amount of carbon dioxide in the mixture re-breathed becomes excessive. While the bag is refilling it is often advisable to open H and allow a breath or two of air to be inspired. It will be noticed that at the beginning of the inhalation the proportion of oxygen was high, about one-third of the bag's contents. This avoids all early suffocative sensations. The proportion was then rapidly reduced in order that the advent of unconsciousness should not be too long delayed. Afterwards oxygen was supplied as symptoms indicated, but it is not easy in practice to give just the right proportions with the simple form of apparatus above described. Better results attend the use of those forms of apparatus which allow the anæsthetist to watch the flow of the gases and which provide a continuous, uniform supply without constant valve manipulation. Moreover, by reason of upright instead of horizontal cylinders, freezing at the valve, which interferes with uniform flow of gas, does not take place. Many good forms of apparatus are now in existence for prolonged administration of nitrous oxide and oxygen. In America, especially, much ingenuity has been expended in order to provide an apparatus with which results superior to those obtainable from Hewitt's apparatus could be achieved in long cases. Gatch appears to have been chiefly responsible for a scientific introduction of re-breathing, and Teter for the first apparatus that was entirely satisfactory in the way that the gases are provided or controlled and in the facilities for

combining them with other anæsthetics at will. Teter's apparatus, which is of formidable bulk, also warms the gases. In some of the earliest severe major operations performed in this country under nitrous oxide and oxygen Teter's apparatus was employed by H. M. Page.[1] His paper contains an excellent discriminating criticism of the method. Page approved of warmed gases. Many workers believe that the warmth provided by re-breathing is sufficient. In the apparatus devised in this country which follows the general line of the American machines warming of the gases is not provided for. In France MM. Desmarest and Amiot have introduced into their apparatus a new principle.[2] They believe that re-breathing is necessary in long administrations, if only for the great economy of gases which it brings about. Re-breathing entails, however, the presence of an excessive amount of carbon dioxide, which has to be got rid of by allowing the bag to be frequently emptied or by some arrangement which permits the re-breathing to be only partial. The authors referred to above conceived the idea of introducing into the respiratory circuit an absorbent of carbon dioxide. Accordingly their apparatus includes a sealed box containing liquid caustic soda, and the re-breathed gases passing over this are entirely deprived of carbonic acid, according to the testimony of the inventors of the apparatus. "To purge the apparatus automatically of the carbon dioxide contained in the mixed gases breathed out without that elimination being accompanied

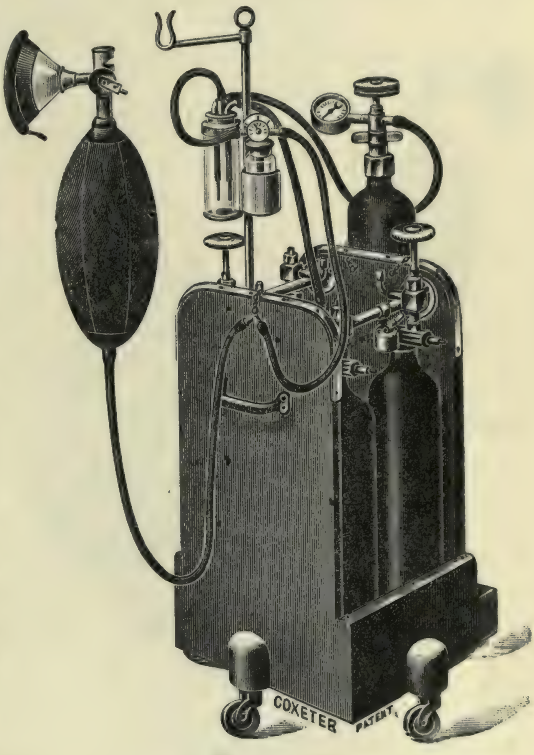


FIG. 25.

[1] *Proc. Royal Soc. Med.*, Vol. 6 (1913).
[2] *La Presse Médicale*, Aug. 21, 1919.

by any loss of nitrous oxide and oxygen, and that thanks to the caustic soda contained in the apparatus, that is the simple modification which has enabled us to obtain regular and prolonged anæsthesia at little expense." Gwathmey, working on the principles laid down by Boothby and Cotton, devised an apparatus of convenient size which allowed very delicate control of the flow of gases and warmed them before they reached the bag. In this apparatus, as in most of the recent machines produced in America, and as in the recent English machines, the flow of gases is made visible by their bubbling through water. This kind of apparatus is therefore often generically classed under the name of "sight-feed machines." For a detailed description and illustrations of many forms of nitrous oxide and oxygen apparatus in use in America the reader should consult Gwathmey's book. Boyle, who has done much to popularize this method of anæsthesia in Great Britain, has devised a machine on the lines of Gwathmey's apparatus (Fig. 25). The control of the gases is secured by a fine adjustment valve. Issuing past this valve, the gases pass to two metal tubes, descending into water contained in an upright glass cylinder. These tubes have a number of holes, and the gases escape from more or fewer of these in accordance with the turning on or off of the fine adjustment reducing valves. The valves are readily worked by hand-keys, and the gases are easily seen bubbling out through the holes. A small spirit lamp warms the reducing valve on the nitrous oxide cylinder. Ether vapour can be taken up in less or greater strength in accordance with the movement of a small indicator on a dial surmounting the stopper of the ether bottle. The latest form of bottle enables the gases to pass over the surface of the ether, taking up but a small amount

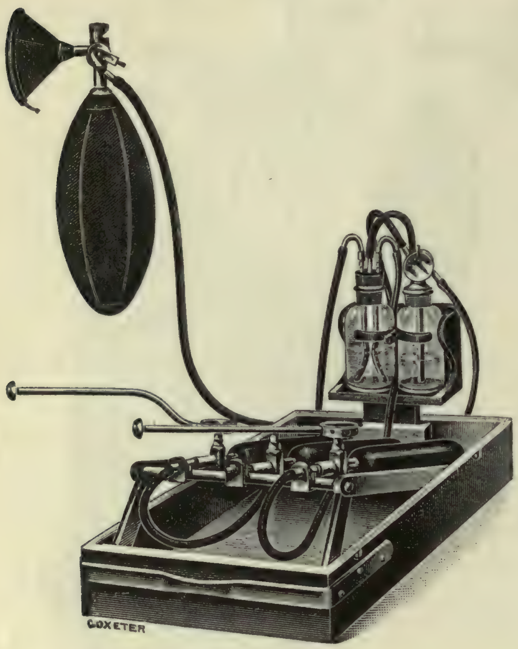


FIG. 25A.

of ether, or through the liquid when a considerable concentration of ether is desired.[1] The gases pass to a small bag connected with a three-way stopcock and face-piece of usual pattern. In practice a double loop of tape elastic may be used to hold the

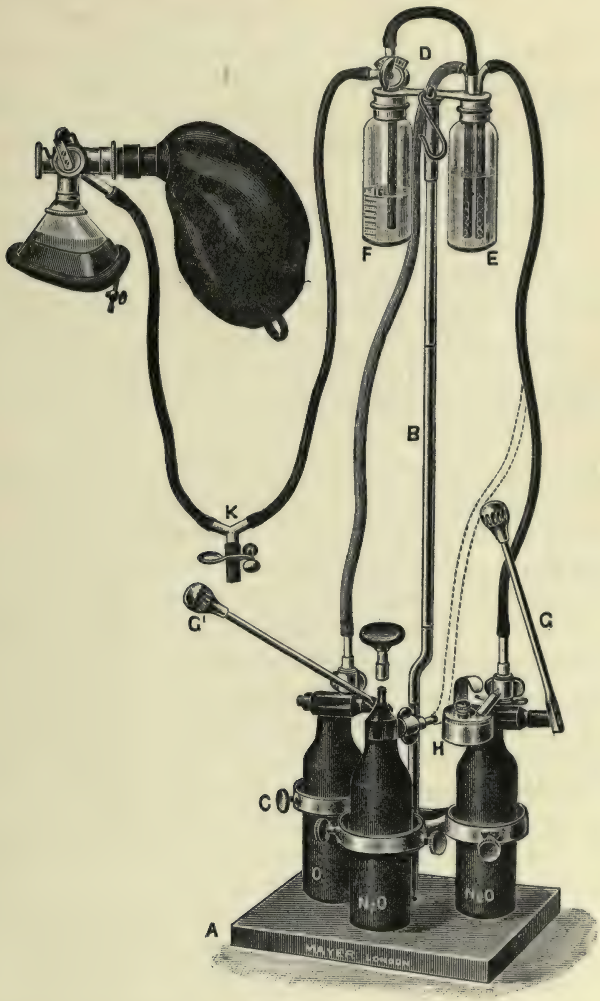


FIG. 26.

face-piece steadily in position. The junction of the loops lies behind the occiput, and each loop comes forward over the mount of the face-piece and is held there by the mount of the stopcock, this being lifted out for a moment from the face-piece to allow the placing of the elastic loops. In the apparatus designed by Geoffrey Marshall (Fig. 25A), to whose work Boyle acknowledges his

[1] *Lancet*, Feb. 19, 1921, p. 390.

indebtedness, the chief difference from the apparatus just described lies in the manner of working the valves. Fine control of the issue of nitrous oxide, a crucial feature in all these forms of apparatus, is obtained in Boyle's machine by a fine adjustment reducing valve. Marshall secures an equally delicate control by using the device of a lever to work the valve of the cylinder. There is no extra reducing valve, but very delicate movement of the main valve is rendered possible by the long-handle lever. Shipway's apparatus (Fig. 26) also presents this feature, and both he and Marshall have been at pains to render their apparatus conveniently portable. If cylinders of 50 gallons capacity are employed, any of the English machines referred to are portable with no great inconvenience. The amounts of the gases required are roughly 100 gallons of nitrous oxide and 30 of oxygen per hour. Thus for private practice two 50-gallon cylinders of nitrous oxide and two 20-gallon cylinders of oxygen, which can be easily transported, suffice for most cases. In hospital, of course, it is more convenient to use larger cylinders and to place the apparatus on a wheeled stand.

In carrying out an *administration* of nitrous oxide and oxygen by one of these sight-feed machines careful attention must be given to the following points. Preliminary sedatives are given as directed above. The face-piece must fit with accuracy, allowing no leakage round the edge. It should not be made of too stiff a material, but should have some pliability and also a fairly wide distensible air-cushion rim. The bag should be about two-thirds full before the face-piece is applied. The mixture it contains should be obtained by turning on one of the oxygen and four of the nitrous oxide holes. A small prop should lie between the bicuspid teeth of one side. For a couple of breaths after the face-piece is applied air should be breathed, then the mixture admitted, the expiratory valve remaining open. The lungs are thus to some extent emptied of their air. Then the expiratory valve is closed and re-breathing begins. The bag should not be tightly distended, for this causes the gases to be inhaled at too great a pressure. The proportion of nitrous oxide is now increased by turning the hand-key so that all the holes available for the gas are opened. The expiratory valve is opened for a breath or two if necessary to prevent the bag becoming too tightly stretched. Unconsciousness is obtained in about a minute. The eyelids, usually flickering during the first minute or so, close and are flaccid. More oxygen is admitted if the colour begins to deepen. Any evidence of obstructed breathing or of jactitation is met by admitting more oxygen. Retching, should it occur, is an indication to lessen the amount of re-breathing. When anæsthesia,

as shown by quiet automatic breathing, absent conjunctival reflex, and relaxed muscles, has been present for two or three minutes, the operation may begin. The proportion of nitrous oxide and oxygen and the extent to which re-breathing is permissible have to be determined in each case by the observation of symptoms. The anæsthetist must keep the *colour free from blueness* and the breathing subject to no more obstruction than is represented by a quiet snore. If he cannot get a sufficient anæsthesia without increasing the nitrous oxide till the patient is cyanosed or there is stertorous breathing, then he must give up the attempt to use nitrous oxide and oxygen only for that individual. In the course of a long administration unfavourable symptoms due to the anæsthetic may arise even without any cyanosis. Enough oxygen may be provided to keep the patient's colour good, and yet he may have inhaled an amount of nitrous oxide which is beginning to tell upon the circulation. When this occurs there is apt to be an excessive secretion of mucus, which may lead to coughing, although more often the patient is too deeply narcotized for this to occur.

Cotton and Boothby state [1] that another symptom of overdose with nitrous oxide in the presence of a sufficiency of oxygen is the occurrence of stertor. *Pallor* will quickly be seen if the excessive administration of nitrous oxide is continued. In fact, depression of the circulation, probably associated with some dilatation of the heart, is the most prominent feature of patients who have received an excessive amount of nitrous oxide while taking enough oxygen to prevent anoxæmic phenomena. The next feature to appear, if the excess is continued, is shallow, gasping respiration. When the correct quantities are being inhaled the condition of a patient under nitrous oxide and oxygen is admirable. The blood pressure is a little raised, the pulse and respirations both only slightly increased above the normal rate. The colour is rosy, the skin not sweating, the pupils moderately dilated, the globes of the eyes fixed or only slightly oscillating, the limbs relaxed, and the conjunctival reflex gone with a corneal reflex easily elicited. During a long administration the corneal sensibility diminishes and may vanish. To keep this condition throughout a long administration requires, however, much practice. The extent to which re-breathing should be used is an important factor in any individual administration and can only be correctly estimated by practice. Cotton and Boothby state that approximately from a quarter to a half of the volume of each respiration should consist of freshly added mixture of nitrous oxide and oxygen. Another factor to be carefully regulated is

[1] Gwathmey's "Anæsthesia," p. 167.

the pressure at which the gases are delivered from the bag. Increased narcosis is quickly brought about by increasing the pressure of nitrous oxide. Some authorities, among whom is Page, believe the gas should never be given under positive pressure, any increase required in the depth of anæsthesia being preferably produced by the introduction of ether.

In order to get complete relaxation with gas and oxygen McKesson [1] employs the process which he calls "secondary saturation." The patient is first brought to extreme narcosis with pure nitrous oxide; then oxygen is given, if necessary under high pressure. Then, the colour being restored, a mixture of 5 to 10 per cent. oxygen with nitrous oxide is given and varied according to the patient's needs.

Difficulties likely to be met in the administration are chiefly due to spasm. Especially early in the inhalation there may be spasm of tongue and of jaw muscles to an extent which seriously obstructs the breathing. The nitrous oxide must be at once cut off and oxygen freely admitted. An unobstructed air-way is even more essential to success with this method than with others. Owing to the face being covered by the face-piece, local obstruction, from collapsing nares, sinking-in cheeks, engorged and retracted tongue, may actually be working detrimentally for some time before it is observed. If the withdrawal of nitrous oxide and admission of oxygen does not at once free the breathing, the face-piece must be removed and the air-way made clear. This may necessitate opening the mouth with a Mason's gag and inserting an artificial air-way. These measures will rarely be needed if a small prop is used between the teeth from the first, as recommended above, if care is taken to prevent the lower jaw from receding, and if cyanosis is strictly avoided. It has been maintained by Trewby [2] that in most patients under nitrous oxide swelling of the back of the tongue from slight asphyxia blocks the oropharyngeal aperture and that breathing tends to become gradually nasal. The same thing happens sometimes with prolonged nitrous oxide and oxygen, usually through too sparing use of oxygen. The question then arises, should the nasal breathing be allowed to continue, or even be facilitated, by passing Silk's nasal tube? I believe that breathing carried on through the nose is rarely efficient enough for continuous safety in these long administrations of nitrous oxide and oxygen. However satisfactory nasal respiration may be in the comparatively short operations of dental surgery, when, moreover, analgesia may meet

[1] *Current Research in Anæsthesia and Analgesia*, December, 1920; and *Proc. Roy. Soc. Med.*, Vol. 15, No. 5, January, 1922.

[2] *Brit. Med. Journal*, July 24, 1903, p. 202.

all requirements, for surgical operations a free route through the mouth should always be obtained.

The *after-effects* which commonly follow are far less than those ensuing upon an equally long administration of other anæsthetics. It does occasionally happen that vomiting, repeated several times, follows a long inhalation of nitrous oxide and oxygen. This is rare, however, and the vomiting is not so exhausting as that which may follow ether, nor is it accompanied by a recurring objectionable taste. In the vast majority of cases the patient is, a few minutes after the finish of the administration, in full possession of his faculties and feeling no discomfort due to the anæsthetic. This is, in fact, one of the greatest advantages to be gained by using this method of anæsthesia for operations on feeble people and for severe operations. The patient can be fed or given stimulants by the mouth very soon after operation. There is usually no post-operative shock comparable to that which may occur after a long ether inhalation when the anæsthetic and stimulant effect of the drug has passed off.

Dangers of Nitrous Oxide and Oxygen in Major Surgery.—"There is no form of anæsthesia at present known which is so devoid of danger as that which results from nitrous oxide when administered with a sufficient percentage of oxygen to prevent all asphyxial complications." When Hewitt wrote these words he had an experience of over 20,000 cases with no death, and no death had been reported by any one else for which nitrous oxide and oxygen was to blame. The anæsthetic had as yet been scarcely used for any but quite short operations. Since its wide employment in major surgery many fatalities have been recorded, and the question may be asked whether its superiority as regards safety is as great over the other anæsthetics, when it comes to long operations, as it undoubtedly is for short procedures. The records make this question a difficult one to answer because of lack of detail in most of the examples recounted. The deaths recorded occurred in many instances to patients whose condition was desperate at the time of operation or to those undergoing operation in itself liable to cause death from shock or hæmorrhage. In many cases nitrous oxide and oxygen were chosen first because of the grave condition of the patient. Mere figures, then, help us very little to estimate the safety of this anæsthetic as compared with others. The most formidable indictment urged against it, that of J. F. Baldwin,[1] appears less damaging than its figures at first suggest when details are sought. Baldwin collected thirteen deaths in some 1,300 administrations. The details furnished are most meagre. We are not told generally anything about the

[1] *Med. Record*, New York, July 29, 1911.

previous condition of the patient. Most of the records give little more than the nature of the operation and the statement that the patient was taking the anæsthetic well when death occurred. Except in one instance, there is no *post mortem* information at all. More important still is the omission of all information as to the experience of the anæsthetist concerned. In other parts of his paper Baldwin does certainly record fatalities during the use of this anæsthetic by highly skilled and experienced administrators. The most striking evidence, indeed, of its possible dangers is found in the following quotation from a letter of Gwathmey's in 1915 : " The death was absolutely uncalled for, and has changed my ideas of the safety of nitrous oxide and oxygen entirely. . . . I believe if I had given him ether the man would have been alive to-day." According to Baldwin's statement, Gwathmey had cognizance of twenty to forty unreported deaths, Teter knew of twenty-six fatalities, Miller of eighteen, and Roosing of thirteen. Without fuller information the mere fact that these deaths have occurred during inhalation of nitrous oxide and oxygen for major operations cannot be regarded as weighty evidence against the safety of the anæsthetic. We must know at least the state of the patient, the amount of operative interference there had been, the likelihood of the anæsthetic having been correctly used, and the conditions found *post mortem* before we can truly appraise the dangers of an anæsthetic from fatalities that occur during its use. There are conditions under which neither nitrous oxide and oxygen nor any other anæsthetic will allow a patient to pass through an operation in safety. Every medical man meets these conditions and has to take the risk because an operation gives the only chance of life to the patient. Familiar examples are late operations upon those suffering from the rupture of an appendix, a duodenal or a gastric ulcer, or operations for the relief of obstruction, or for the checking of hæmorrhage after some violent accident. In these " touch and go " cases there will be a large percentage mortality for whatever anæsthetic is used. The anæsthetic is not to blame for the death, and so far as nitrous oxide and oxygen is concerned, it may be justly claimed that the deaths are probably fewer in proportion with this than with other anæsthetics. Yet it is certain that danger may be brought about by this anæsthetic too of itself, and that more skill and practice are required to avert this danger than when simpler forms of anæsthesia are used. Some of the fatalities are recorded as having occurred with great suddenness and are attributed to syncope. In the majority it is obvious that there was impeded respiration, and it is here that danger may most easily be reached during an inhalation of nitrous oxide and oxygen. Obstruction

to the breathing is easily caused by spasm and by cyanosis during the use of this anæsthetic. Secondarily to hampered breathing, a rapid and fatal failure of the heart muscle may quickly occur in feeble or diseased hearts, and at no long interval, even if the organ is normal. Especially is this true when the inhalation has been going on for a considerable length of time. The matter is further considered under the heading of fatalities. Here we may sum up by saying that for normal individuals nitrous oxide and oxygen in major surgery, provided that it is given by one who is well versed in its use, is probably the safest anæsthetic at our disposal, provided also that its use is restricted to suitable subjects. Any condition involving narrowing of any part of the air passages renders the patient unsuitable for nitrous oxide and oxygen.

Nitrous oxide and oxygen used in the way described has especial advantages for certain classes of subjects :—

(1) Patients in a state of *shock* recover more favourably than if other anæsthetics are used. According to Crile's experimental work, nitrous oxide protects the brain cells more effectually than do either chloroform or ether from traumatic stimuli (see p. 326).

(2) Persons already feeble or septic from prolonged illness. Here the non-toxic nature of nitrous oxide gives it superiority over other drugs, as does the greater probability of freedom from after-sickness.

(3) Those suffering from diabetes. Post-operative coma is less likely than after the use of the more potent anæsthetics.

(4) Patients having long operations on parts not particularly sensitive, *e.g.*, long bone operations ; also the subjects of long superficial operations, *e.g.*, for plastic repair of the face (Rowbotham and Magill).

(5) People who have on previous occasions suffered severely from after-effects of other anæsthetics.

(6) Women undergoing Cæsarean section on account of albuminuria. On several occasions the author has had the opportunity of giving nitrous oxide and oxygen under these conditions. The result has been most satisfactory to surgeon and to patient.

It must be remembered when selecting this anæsthetic that the narcosis which it provides is light as compared with that from ether or chloroform. Therefore reflex movements occur much more readily than when these drugs are employed. If such movement is highly undesirable, then unaided nitrous oxide and oxygen should not be relied on even for the skin incision, except in the case of very easy subjects.

The Use of Nitrous Oxide and Oxygen in Labour

It has been urged that the fleeting character of the anæsthetic properties of nitrous oxide makes it especially adaptable for obstetrical conditions.[1] The ideal aimed at is to apply to the transient recurring pains of labour an agent which can quickly and harmlessly counteract those pains and cease to act directly it is withdrawn. No doubt nitrous oxide, of all anæsthetics, most nearly facilitates this ideal. Those who advocate its use in labour claim a further advantage—viz., that a state of analgesia can be maintained by its use, and that although the patient is insensible to pain during that state, yet she can obey the suggestions of the accoucheur and aid in her delivery at his bidding. In this way it is maintained that nitrous oxide actually shortens the duration of labour. The patient who feels no pain from her uterine contractions will obviously assist more readily than she who is asked to accentuate something the agony of which she is struggling to endure. When the head is passing over the perineum true anæsthesia should be produced. At this time, and if any instrumental interference is needed, nitrous oxide and oxygen are generally insufficient. The administrations of the anæsthetic are to be begun during the first stage of labour whenever the pains seriously affect the sensibility of the patient. In the case of a primipara this will usually be when the os admits but three or four fingers. With multiparæ labour is generally much further advanced before the anæsthetic is needed. Naturally individuals, both women who have had previous confinements and those who have not, vary greatly as to the point which has been reached before it is advisable to provide them with analgesia. The anæsthetic must be applied at the first indications of a uterine contraction so that enough gas is inhaled before the contraction reaches a maximum. Actual pain is thus prevented, and then the administration is discontinued, or the gas so diluted with oxygen that full unconsciousness is not obtained. The pains of uterine contraction are generally forestalled by about six breaths of nitrous oxide with enough oxygen to prevent any cyanosis. The patient is then instructed to hold her breath and to bear down. The anæsthetic is withdrawn directly the uterine contraction is passing off. Used in this intermittent fashion for the provision of analgesia, nitrous oxide and oxygen can be given over long periods of time without harm to the patient or to the infant. The mother is less exhausted after the birth of the infant than if she has inhaled chloroform or ether for the same length of time. The baby is so unaffected by the gas that early feeding is

[1] *Medical Record*, Feb. 28, 1920, p. 356.

always practicable. Guedel, who has used "gas and oxygen" for patients in labour since 1910, has devised an apparatus permitting self-administration. Some anæsthetists have employed the nasal route with good results. The reader who is interested in the use of nitrous oxide and oxygen in labour should consult a pamphlet issued by the National Anæsthesia Research Society in America in 1920. Coburn [1] has maintained nitrous oxide analgesia for a patient in labour for as long as nine hours. Apparently so little nitrous oxide reaches the infant, owing to the contractions of the uterus, that the baby seldom needs any stimulus after birth to start its respiration. The analgesia and anæsthesia of nitrous oxide and oxygen do not diminish the uterine contractions. Nor do they affect the patient's metabolism or blood pressure in the way that long inhalations of more toxic anæsthetics may do. Thus the general condition of the patient is well maintained and the risk of post-partum hæmorrhage diminished.

[1] *Medical Record*, New York, July 29, 1911.

CHAPTER XI

ADMINISTRATION OF CHLOROFORM

THERE are no closed methods of giving chloroform, since the vapour must always be freely diluted with air. This end is reached by giving the drug either—

(1) From an open mask, on which it is supplied from a drop bottle; or

(2) By pumping air or oxygen through or over chloroform, the vapour being delivered through a mask or tube (Junker's apparatus and Shipway's apparatus); or

(3) By dosimetric apparatus, which supplies definite percentages of chloroform vapour either (*a*) by the draw-over system (Vernon-Harcourt's apparatus), or (*b*) by the plenum system (Roth-Draeger, Dubois, Waller, and other apparatus).

None of the apparatus used for chloroform administration permits of re-breathing. In all methods the principle of *continuous administration* of a *uniform vapour* is to be observed.

Drop-bottle and Mask.—This method has the merits of simplicity, convenience and wide range of power. It has the corresponding defect that it easily becomes dangerous. Therefore it is wise that the administration, or at least the principles of administration, of chloroform should first be thoroughly learned by the use of methods in which the dosage is accurately controlled. When the student understands the importance of controlling the vapour strength of chloroform and realizes both the ease with which a dangerously strong vapour can be supplied and the symptoms to which it can give rise, then he may enjoy the convenience of the drop method. Moreover, since circumstances will often limit him to this when he leaves hospital, it is essential that he should gain experience with it while under supervision. The mask to be used is either that known as Skinner's or Schimmelbusch's, or one of the numerous similar forms (Figs. 7 and 8). A modified form especially convenient during operation on the eye is shown in Fig. 24. The essential features are that it shall be covered with one layer of material on which chloroform liquid easily spreads, and that it shall be convenient to hold in such a position as to cover without

touching the patient's nose and mouth. Domette and thin flannel are good materials for the mask cover. Towelling is preferred by some and a few layers of fine gauze or a single layer of lint by others. Whatever is used, it must not be of a thickness or consistency which allows the liquid to pool. After each administration the frame can be boiled and the cover material renewed. This ensures a perfect cleanliness, which is not so easily obtained with the apparatus needed for other methods. The

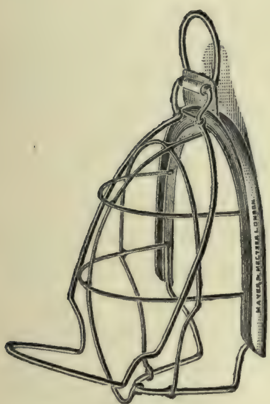


FIG. 27.

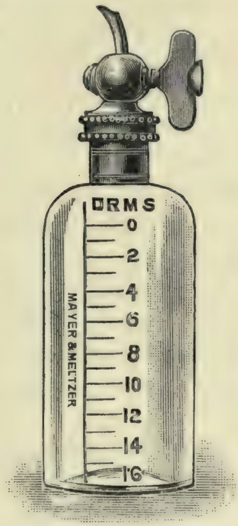


FIG. 28.

FIG. 29.

drop-bottle may be of the Hewitt (Fig. 28) or Thomas (Fig. 29) pattern ; or an ordinary glass bottle with a cork in which a groove is cut and a wisp of gauze inserted answers quite well. Glass drop-bottles are also commonly used. When glass bottles are used for chloroform they should be of a brown colour, not only because the drug is better protected in this way, but to distinguish them plainly from those holding other liquids.

Administration.—Unless for exceptional conditions, the patient lies flat on his back, the head slightly raised by one pillow and turned to the side away from the operator. It is a common mistake to place the patient's head level with his chest ; few persons can lie comfortably with the head so low, and there is no valid reason why they should be asked to start their anæsthetic sleep in this discomfort. Patients frequently ask, "Shall I breathe through the mouth or the nose ?" Tell them to breathe naturally, not to try, and just to keep the mouth a little open. Hold the mask a couple of inches off the face and put on it one drop of essential oil of orange (ol. aurant. dulc.).

The pleasant odour encourages the patient's breathing and to a great extent permeates the air of the room, alleviating other odours. Now let chloroform drop upon the mask at such a rate that a drop reaches it with every inspiration. This slow rate of dropping is kept up for the first two minutes, and then is hastened till at least half the mask is kept moist at the end of four minutes. The anæsthetist's object is to supply a continuous and gradually increasing dose. There must be no moment when the mask is dry, alternating with others when it holds a drachm or so of the liquid. With the increasing supplies of the drug the mask is also allowed to descend nearer to the face, on which, however, it is not allowed to rest. In this way a vapour of about 2 per cent. chloroform is constantly supplied. By the end of six minutes the whole surface of the mask may be wet with chloroform. About 2 drachms of the liquid will have been used, and it will be poured out at about the rate of 1 drachm every four minutes for the rest of the administration. From the very beginning the patient's breathing is listened to carefully. Any holding of the breath in the early stages or coughing is responded to by withdrawal of the mask. Swallowing movements which may momentarily interrupt the breathing do not require the same measure. Slight salivation, often accompanied by spitting in the ill-bred, is met by wiping the lips. Retching or attempted vomiting occur either quite early from nervousness, when the patient needs encouragement and steady persistence with the administration, or else later, when they show that the chloroform is being given too slowly. Consciousness is generally lost within four minutes and anæsthesia present within six. At first, if the vapour is not objected to and the breath not held, the respiration usually quickens. The face flushes a little, the pulse is faster, and rambling talk begins. This goes on to shouting with some subjects. Later speech degenerates into inarticulate sounds. Various movements may take place in these first three or four minutes, often directed to removing the mask, to sitting up, or to holding on to any bystander. Later the limbs may be rigid, or there may be violently excited movement of them as well as of the trunk. The neck muscles are at this time stiffly contracted, and the breath may be held with spasm of the jaws and of the respiratory muscles. This "excitement stage" is after consciousness has gone, a fact that is often lost sight of by those who appeal to the senseless patient to "take it quietly" and so on. At this time only so much restraint of the patient should be exercised as is needed to keep him from jerking himself from the table or otherwise damaging his own or another's person. It is a mistake to attempt forcibly to keep him still. The end of the

excitement stage is usually marked by several loud snoring or stertorous breaths and complete flaccidity of the muscles. The extent to which these phenomena are observed varies, of course, greatly with different patients. The plethoric, muscular, thick-set man, particularly if he is accustomed to alcohol, will give the longest and most violent exhibition of muscular spasm and excitement. The thin, frail woman and the child will commonly pass into unconsciousness and into relaxation with no evidence of excitement at all beyond perhaps a little incoherent talking. The danger of the violently contracted muscles and restricted or suspended breathing is one reason why *induction by chloroform is not to be chosen as a routine.* A strain is thrown upon the right side of the heart, which is distended owing to the temporary lapse of respiration. At the same time the heart muscle is subjected to the depressing influence of the intaken chloroform, and there is little doubt that some fatalities which have occurred during the induction stage are to be explained in this way. A catastrophe of this kind may occur during the inhalation of what is physiologically a safe strength of vapour. It is the combination of suspended breathing and muscular contraction with uneliminated chloroform that promotes the danger. Whether or not fibrillation of the ventricle is the immediate mode of death in these fatalities before anæsthesia has been reached, the practical lesson is the same—viz., since we know no means of obviating the occurrence of this dangerous stage with chloroform induction, avoid induction by chloroform. It is true that this muscular excitement and respiratory interruption are more prone to occur if chloroform is irregularly given or too suddenly increased in strength, and that to that extent they are less easily avoided by the drop-bottle method than by the regulating apparatus described later. They are not always wholly absent, however, even with the regular and controlled dosage of the machines. Moreover, the dangerous stage of light narcosis, when both fibrillation and exaggerated vagus action are easily evoked, must be passed through, whatever method of administration is adopted—another potent reason for not inducing anæsthesia with chloroform.

When anæsthesia is reached the colour of the face is generally a little paler than when induction began, and remains so, getting, indeed, slightly more pallid in the course of a prolonged administration. The pupils, which generally dilate during induction, become contracted in anæsthesia. The light reflex remains. The size of the pupil is very variable, however, during the first quarter of an hour or so of an operation under chloroform, and cannot be used then as a guide to the depth of narcosis. It often dilates as a result of the incision or in response to other peripheral stimuli,

or varies with respiration. Generally, however, it settles down to a small size (2 to 3 mm.) after about a quarter of an hour, and after that grows larger or smaller in accordance with a deeper or lighter degree of narcosis. It is smaller than the usual pupil during ether narcosis. The globes of the eye move irregularly, or there may be nystagmus during the early stages of narcosis. In anæsthesia they are generally still and in the middle line. The conjunctival reflex is abolished soon after unconsciousness is reached, but the corneal reflex persists generally till anæsthesia is fully established. When it has gone it may be recalled by the stimulus of the first incision, vanishing again as anæsthesia continues.

The path to anæsthesia is often smoother than that described above. There may be no visible excitement and breathing may be gentle throughout. Sometimes, indeed, the respiration is so quiet that a state of so-called "*false anæsthesia*" is entered. The patient lies with slight pallor, very gentle breathing, sluggish lid reflexes, and relaxed limbs, apparently fully narcotized. Yet if an incision were now made there would be violent reflex movements and very likely a cry. Young children in particular are easily lulled into this condition by dilute chloroform vapour. If the anæsthetist is in any doubt, through absence of all obvious evidence that the third stage has been reached, whether his patient is anæsthetized or not, he should stimulate the respiration by briskly rubbing the face and lips and pour a couple of drachms of ether upon the mask. If the narcosis is still very light, there will be swallowing or coughing or holding of the breath. If the patient is really in anæsthesia, he will breathe the strong ether vapour without interruption. When the apparatus of Junker or of Shipway is to be used it is still desirable to begin induction with drops on a mask. The vapour is more easily inhaled than when presented with the draught from a hand-pump. It is only necessary to employ drops for the first two minutes. Then the patient's sensibility is blurred enough for him to inhale the vapour supplied by gentle squeezes of the hand-pump. The best mask to use with the Junker or the Shipway is one covered with domette and resembling the ordinary Skinner's mask, but the frame is perforated. The drops, in fact, can be supplied on this same mask before the pumping apparatus is brought into play. When the pumping starts the mask is allowed to rest upon the patient's face and with each inspiration a gentle squeeze is given to the hand-pump. In the course of induction the squeezes are made more and more forcible. A stronger and stronger vapour is thus supplied, till after about five minutes the apparatus should be giving the highest percentage vapour of

which it is capable when properly used. It must be borne in mind that with Junker's apparatus and with Shipway's the exact strength of vapour supplied is uncertain and varies with several factors. The amount of chloroform taken up by the air pumped through it varies with the strength and rapidity of the pumping, with the temperature of the bottle and of the chloroform, and with the quantity of the latter present in the bottle. It is increased by any shaking or moving of the bottle. In use, therefore, we must not regard these machines as giving accurately controlled percentage vapours, although they are designed to keep, and in practice do keep, the strength of chloroform roughly within the physiologically safe limit of about 2 to 3 per cent.

FIG. 30.

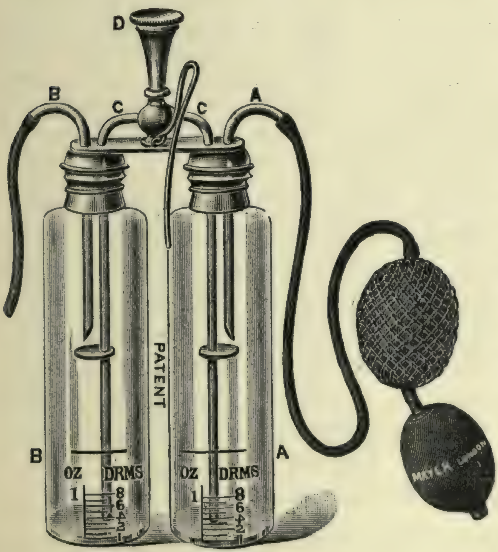


FIG. 31.

Junker's inhaler (Fig. 30) was invented for use with trichloride of methylene. The original form had a vulcanite face-piece and air-slot and no filling funnel. The principle of the apparatus is the driving of a current of air by means of a hand-pump through a bottle of chloroform, from which the air, laden with chloroform vapour, escapes by an exit tube and reaches the face-piece. The face-piece consists of a Skinner's mask so constructed that

the chloroform vapour escapes by a series of holes in the wind-rib of the frame. The mask is covered by a flannel cap or layer of domette, and thus the face-piece can be pervaded with vapour instead of the chloroform intermittently puffing into the face. The bottle, which should be upright and still during use, is graduated to 1 ounce. Two metal tubes enter the bottle—a long one, which passes down to the chloroform, and a short one, which leads the vapour off to the face-piece. It is important to see that the corresponding indiarubber tubes are properly attached—viz., that from the bellows to the long metal tube and that to the face-piece to the short metal tube. By fitting the tubes wrongly it is possible to drive liquid chloroform into the face-piece, especially if the bottle is tilted in use. This accident has occurred with fatal results on several occasions,[1] and is especially dangerous when, instead of the face-piece, a metal tube is being used to convey the vapour to the mouth or to the trachea. With the ordinary form of Junker, liquid chloroform cannot be sent on to the patient if—

(1) The instrument is correctly fitted together ;

(2) Chloroform is not put into the bottle above the top figure marked on it ;

(3) The bottle is kept strictly upright.

FIG. 32.

In order to make the accident impossible even if these precautions are not all observed, Hewitt modified the apparatus by placing the efferent tube within the afferent and leading it out at right angles from the latter. The tubes cannot be wrongly adjusted in this modified instrument, and, unless the bottle is grossly overfilled and tilted, it is impossible to get liquid chloroform into the efferent tube. Messrs. Mayer and Phelps have also devised a safe form of Junker which is figured above (Fig. 31).

Whatever apparatus is employed should be tested with chloroform in it immediately before employment. One of the chief uses of the Junker is to maintain anæsthesia during operations about the face and neck which make the use of a mask impossible. The face-piece is then replaced by a soft metal tube fitted on to the efferent rubber tube and placed in the side of the mouth, or into the upper end of the tracheotomy or laryngotomy tube, as the case may be. The tube being made of soft, not rigid, metal, it can be bent to various angles to suit the exigencies of each case. Sometimes during operations within the mouth it is more con-

[1] *Trans. Soc. Anæsth.*, Vol. 6, p. 57, and *Brit. Med. Journal*, Jan. 24, 1903, p. 195.

venient to use a rubber catheter fitted on to the efferent tube of the Junker or Shipway, in place of the soft metal tube, and to pass the catheter into the nose. Another device often useful in these cases is the combined tongue depressor and delivery tube designed by Longhurst (Fig. 32), and this is often most convenient for maintaining anæsthesia during long operations on glands of the neck. It enables the anæsthetist to keep the jaw forward and supply the necessary vapour without his hands encroaching on the surgeon's area. The modification of Mason's gag devised by Hewitt is often useful when chloroform is to be given for nose and mouth operations. It has a tube for transmitting chloroform vapour fitted along the blades of the gag. Shipway's warm vapour apparatus (described on p. 116), arranged so as to cut out the ether supply and work from the chloroform bottle, is efficient for all occasions suitable to the use of a Junker. When it is employed with a metal tube or with a face-piece which delivers the vapour through holes in metal it must not be regarded as a means of giving warm vapour. The warmth is so largely lost to the metal. As an apparatus for keeping up easily a uniform supply of dilute vapour it is excellent, and the large size of the hand-pump makes compression less fatiguing than it is with the smaller rubber balls commonly fitted to Junker's instrument.

The *Roth-Dräger apparatus*, which is widely used on the Continent, is rarely seen in Great Britain. It is an excellent machine for use in institutions, but too cumbersome and complicated to be taken about. It supplies a weak vapour of air, chloroform, and oxygen through a closely fitting face piece provided with valves and air-slot. *Dubois' machine* [1] and *Waller's chloroform balance* [2] both give accurate percentage vapours on the plenum system. From the point of view of practice, however, they meet with the same objection as the Roth-Dräger, and so demand no detailed description here. *Professor Hobday's* apparatus, in which air is driven over chloroform by an electric motor while the strength of the vapour is exactly adjusted, has given most satisfactory results with animals. As regards apparatus working on the plenum system, it may be said generally that, with the exception of the Junker or the Shipway, the necessity for elaboration makes these machines inapplicable to ordinary practice. The other type of chloroform regulating inhaler, that which works on the "*draw-over*" plan, is best exemplified by the Vernon Harcourt apparatus. In plenum apparatus the strength of vapour supplied is independent of the force and rapidity of the respirations, although, of course, these affect the

[1] "Anesthesie Physiologique," Paris, 1895, p. 106.
[2] Hewitt, *loc. cit.*, p. 104.

actual amount of chloroform inhaled. In draw-over apparatus, on the other hand, the actual evaporation of the chloroform is determined by the patient's breathing. The arrangements of the apparatus, however, limit the strength of the vapour which can possibly be delivered from the chloroform to 2 per cent.

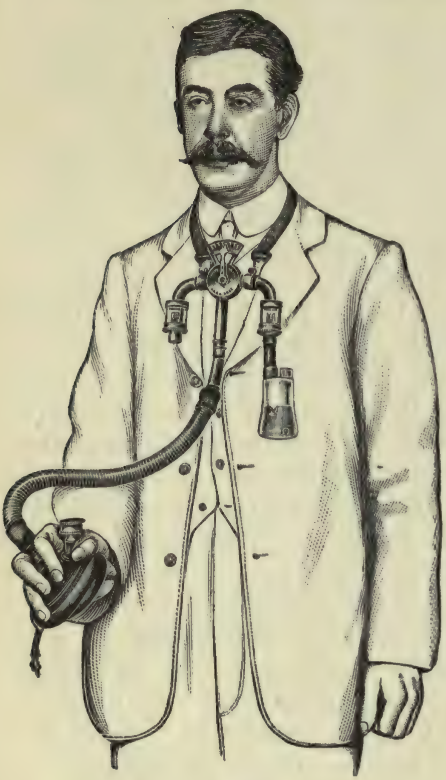


FIG. 33.

FIG. 33A.

FIG. 34.

This percentage can be heightened to 2·5 or 3 by a small additional contrivance.

The Vernon Harcourt apparatus (Figs. 33—34) consists of a two-necked bottle, which holds chloroform up to the top of the conical portion, connecting with a closely-fitting face-piece by a vertical metal stem with two horizontal branches. The face-piece can be far removed from the rest of the apparatus by long tubing placed between it and the metal stem. In this way the chloroform bottle can be fixed on a stand or slung round the administrator's neck, and thus be kept quite still. Any agitation of the bottle upsets the accuracy of the recorded percentages of vapour. (So does any marked alteration of the temperature of the bottle.) The coloured glass beads dropped into the chloroform show when the temperature is within the range 16° to 18° C. If the liquid cools below 16°, both beads float; if it warms above 18°, both sink. With beads floating the proportion of chloroform inhaled will be less, and with both sinking more than the stop-

cock indicates. In use, if the bottle cools below 16°, it can be warmed by the hand or by a spirit lamp or water bath. The stopcock, to which a pointer is fitted, is so made that, when the pointer is at the end of the arc nearest to the chloroform bottle, the maximum quantity is being inhaled; when the pointer is at the other end of the arc only air can be breathed. At intermediate positions the strength of vapour depends on the proximity of the pointer to the chloroform bottle end of the arc. Valves on the two branches of the stems prevent re-breathing and also indicate the proper working of the stopcock. When the pointer is midway both valves open, when it is at either end of the scale only one opens, and at intermediate positions one opens more and the other less, according to the direction in which the pointer is moved. The valves being made of mica, the little click of their movement with respiration gives an audible guide to the anæsthetist. An expiratory valve is placed either in the face-piece or on the vertical stem. The dimensions and shape of the two-necked bottle were the result of experiment. They are proportioned so that with the average rate of breathing and a temperature between 16° and 18° C. the yield of chloroform vapour is the strength indicated on the dial. The nearness of the two necks of the bottle to each other and the distance between these and the surface of the chloroform lessens the variation caused in the proportion of inhaled air to chloroform due to abnormally slow or deep breathing.

In using the Vernon-Harcourt inhaler the face-piece is to be fitted accurately to the patient's face. Any leakage around the rim of course vitiates the accurate working of the instrument. Two ounces of chloroform are introduced into the bottle and the glass beads dropped on to the liquid. The patient's face is turned to one side and the anæsthetist grasps the face-piece with his left hand, while his right, placed behind the patient's lower jaw, steadies the face firmly into the face-piece. The strength of the vapour is gradually increased by turning the pointer. At first this should be done very slowly. If there is struggling the pointer is kept stationary till it subsides, but the face-piece is not lifted from the face unless some cyanosis appears. For most patients anæsthesia is not induced without using the highest percentage vapour that the instrument can yield, and the induction takes about six to eight minutes. There are, of course, wide variations in the amounts required, according to the physique and nature of the patient, just as there are with any form of administration. Usually, however, anæsthesia can be satisfactorily obtained in the manner just described, and can be maintained with the pointer at 1·5. During long operations it can often be put back to 1 or to 0·5. On the other hand, difficult subjects may require the increased percentage tube both for the attainment of full anæsthesia and for its maintenance during operations that promote violent sensory stimulation. The tube providing for increased percentage of vapour is a small metal tube which fits into the open neck of the bottle. To obtain a 2·5 per cent. vapour the larger end of the tube, and for a 3 per

cent. the smaller end, is inserted into the bottle. The Harcourt inhaler finds perhaps its most appropriate place when used for maintaining anæsthesia during long operations where a comparatively light narcosis suffices. For operations upon the head, for instance, and mastoid operations it is excellent. Some subjects, however, are not well suited by any closely fitting face-piece, and for them, of course, this inhaler should not be used. These are generally patients entirely edentalous or else those with obstructed nasal passages, narrow palate, and crowded jaws. To enable oxygen to be used with his inhaler, Harcourt has devised an addition by means of which the apparatus works on the plenum instead of the draw-over system. It has, however, under those circumstances no practical advantage over the Shipway or Junker apparatus with an oxygen cylinder attached in place of the hand-pump. Other regulating inhalers on the draw-over principle are those of Levy [1] and of Hirsch.[1] Levy's provides for a vapour reaching the strength of 4 per cent. A special point about it is that the chloroform current is so managed that the dilution with air becomes greater the feebler are the inspirations. A defect of most draw-over apparatus is that the concentration of the vapour tends to increase with the decreasing strength of the breathing. Hirsch's inhaler is of comparatively simple construction. It is made after a model which Waller evolved from Regnard's apparatus. Experience with Waller's instrument led me to regard it as providing too weak a vapour for practical use. Induction was inconveniently protracted. Hirsch's apparatus is stated to give satisfactory results. It is often desirable to give *oxygen with chloroform.* Anæmic patients taking chloroform are always better for the addition of oxygen. Patients in a state of shock and those who are suffering from any respiratory difficulty or disease are also benefited by the addition of oxygen. When a drop-bottle and mask are being used the tube from an oxygen cylinder may be allowed to rest beneath the mask at the corner of the mouth. A gentle stream of oxygen is allowed to flow constantly from the mouth of the tube. The tube is kept in place either by the anæsthetist or by passing through a safety-pin fixed into the pillow. When the Junker or Shipway is employed the tube from the oxygen cylinder is simply fitted on to the afferent metal tube of the apparatus in place of the tube from the hand-pump. Very feeble patients are sometimes best treated by allowing the oxygen on its way to the chloroform to pass through a Woulff's bottle containing absolute alcohol. Hugh Phillips [2]

[1] *Lancet,* May 27, 1905, p. 1413, and *ibid.,* April 1, 1916.

[2] *Proc. Royal Soc. Med.,* December, 1917, Vol. 11, No. 2 (Anæsthetic Section), p. 13.

showed at the Royal Society of Medicine an apparatus for giving oxygen with either chloroform or ether. An oxygen cylinder connects with a copper water-tank, and this with a three-bottle apparatus containing chloroform, ether, and plain water. The apparatus is simple, but bulky.

Intra-tracheal insufflation of chloroform has been practised by Guisez,[1] and in this country by Fairlie [2] and by Mott.[3] The results were good, particularly as regards complete absence of after-effects, but there does not seem to be any advantage over the much safer employment of ether by the same method. Guisez attributes the entire absence of vomiting after intra-tracheal insufflation to the fact that, owing to the presence of the tube and of pharyngeal packing, swallowing movements are impossible. Thus no saliva impregnated with chloroform, no mucus, and no chloroform vapour cân be ingested. It is to the swallowing of these three things, and especially chloroform vapour, that Guisez attributes post-anæsthetic vomiting. Post-anæsthetic vomiting is certainly lessened by any measure which lessens the swallowing of saliva and mucus and the anæsthetic. Evidence of that is given by the use of atropine and by the comparative freedom from sickness after rectal anæsthesia. Yet the swallowing is not the sole, even if the chief, cause of the vomiting, for the stomach may be washed free and vomiting occur after anæsthesia nevertheless.

The symptoms of chloroform narcosis during its four stages may now be briefly stated.

First Stage.—Starting with a very weak vapour, the anæsthetist generally meets with no objection from the patient. Very commonly the latter remarks that he is " not going off," and this observation is often on the tip of his tongue as he slips into oblivion. Often the beating of the heart is remarked upon by the patient, and he commonly notices a feeling of warmth and a sickly taste. There is little swallowing or holding of the breath during consciousness, unless too strong a vapour is used. The eyes are often kept open during induction, and the patient should be asked to keep them shut. A sudden movement of the head is commonly the first indication of the effects of the inhalation. Soon incoherent talking may mark the onset of the *second stage*, when proper consciousness is no longer present. Now there may follow vigorous sitting-up movements with rigid out-stretching of the arms. Excited muttering of words, degenerating into meaningless noises and into prolonged holding of the breath with

[1] *Presse Medicale*, Aug. 29, 1918, p. 441.
[2] *Glasgow Med. Journal*, December, 1917, p. 334.
[3] *Proc. Roy. Soc. Med.*, Vol. 13, p. 25.

muscular rigidity, is often present on the part of muscular and alcoholic subjects. During this time a steady dilute vapour is to be offered and the respiration encouraged by rubbing the face and lips. Care is to be taken that the airway is not obstructed, the lower jaw being held well forward with a small prop between the teeth. Under this treatment the spasm soon subsides relaxation follows, and with a stertorous inspiration the *third stage* is entered. The second stage does not always show these spasmodic phenomena. Sometimes it is merely marked by increased vigour of breathing, very slight muscular rigidity, then some inspiratory stridor, and then relaxation. At other times a very quiet form of breathing appears, accompanied by pallor. This may culminate in vomiting if the breathing is not stimulated. When there is much muscular spasm and holding of the breath the second stage is a period of danger, as has already been indicated. Strain is thrown upon the right side of the heart by the inactivity of the lungs. At the same time chloroform is exerting its depressing effect on the cardiac muscle. The combination of these two influences may account for the sudden heart failure which has occasionally occurred at this stage, and is most to be dreaded if the patient has a poorly-acting or fatty heart muscle. It is the practice of some anæsthetists when this spasm occurs with the second stage to pour ether upon the mask in place of chloroform until free respiration is re-established. The latter, however, is the most important practical step to be secured. The breathing when spasm relaxes is resumed with vigour, and it has been urged by those who believe only in over-dose deaths from chloroform that during these deep breaths an excessive amount of chloroform is rapidly inhaled, and that in this way are to be explained fatalities that have occurred before the establishment of full anæsthesia. Whatever may be the physiological truth of these fatalities, the practical lesson is that which we have already drawn—viz., that induction with chloroform is to be avoided whenever possible. When it must be employed, however, the dangers of the second stage are minimized by keeping up a continuous supply of a weak vapour, by avoiding respiratory obstruction, and by stimulating breathing when it hesitates. Probably the *substitution of ether for chloroform* as soon as spasm shows itself is a measure of safety. According to Levy's views it should on theoretical grounds add to the danger by introducing a fresh stimulus (see p. 60). The pupils during the second stage are dilated, but re-act to light and fluctuate in size. The eyeballs are usually not still, but move in a co-ordinated manner. Theconjunctival reflex is generally gone by the end of the second stage, but the cornea remains faintly

sensitive. The circulation depends largely on the manner of the respiration. When there is not much spasmodic interruption of the breathing the pulse is found at the close of the second stage to be regular, of good size, and little faster than the normal. During spasm and interrupted respiration the pulse may become very rapid and feeble. Similarly, it is felt to be poor during the pallor and shallow breathing described as sometimes occurring in the second stage, and ending in an act of vomiting. Some salivation leading to a desire to spit is often seen in the second stage. Sensation disappears, and at ordinary confinements, for example, it is not found necessary to deepen narcosis beyond this stage. Dreams occur, at any rate in the earlier part of the second stage. They are probably not remembered when a long anæsthesia follows, though those that may arise when a similar stage of narcosis is again reached during recovery may be remembered after consciousness.

The third stage is noticeably characterised by *muscular relaxation*, with which goes a quieter form of breathing. There is sometimes a crowing inspiration, due to slight laryngeal spasm. More often the breathing is almost noiseless or with a soft snore. The mucus and congestion often associated with ether anæsthesia are absent. The colour is slightly paler than the normal. The pulse is slower than during the preceding stage and quite regular. There is a slight but steady fall in blood pressure, as there is also a fall in the body temperature. The eyeballs are either fixed or move slowly and without co-ordination. The *pupil* is moderately contracted, usually about 2·5 mm. Its size, however, must not be used to estimate the depth of narcosis till anæsthesia has been present about fifteen minutes. During the early stages of an operation the pupil is much affected, just as the breathing may be, by afferent impulses, and a widely dilated pupil at this time does not necessarily mean a very deep narcosis. Later on, and especially if the effect of diminishing and increasing the chloroform has been seen to be to contract and to widen the pupil, this becomes a reliable guide. A *wide pupil with an insensitive cornea*, then, means a *deep narcosis*. The *corneal reflex* should be just obtainable when the third stage is first established. For operations other than those upon the abdomen or on particularly sensitive parts it should be kept in this state. Allowance must be made, however, for the condition and nature of the patient. Thus the very robust or alcoholic patient must be brought to the pitch at which there is no lid reflex when the cornea is stimulated, or else he is almost sure to show reflex movements during operation. The feeble and the anæmic individual, on the other hand, may be allowed to retain a corneal response,

and will remain properly immobile even during the most trying operation.

Certain *muscular movements* independent of the lightness of narcosis, and commonly seen only in chloroform anæsthesia, deserve attention. If not understood they may lead to the impression that more anæsthetic is needed. Actually the opposite is the truth, for these movements occur generally when narcosis is deep and when more air, not more chloroform, is required. They most usually take the form of clonic contractions of the pectoral muscles, causing the arms to be rhythmically twitched towards the body. Sometimes the movements are confined to the fingers and sometimes to the legs. They can almost invariably be got rid of by withdrawing chloroform and ensuring free entrance of air into the lungs.

The respiration and the circulation during the *maintenance of chloroform anæsthesia* are much affected by the operation in progress. The condition described as characteristic of this stage—viz., quiet breathing, slightly pale colour, regular pulse, medium pupil, and relaxed muscles—could no doubt be kept unaltered for long periods of time by continuous and steady administration of a weak chloroform vapour if no operation were being performed. In practice the patient is subjected to many interferences, and we must try to picture these to the reader. Firstly we may deal with *abnormal variations in breathing* that occur *early* in chloroform narcosis. We may pass over those which are due to conscious effort on the patient's part, such as prolonged holding of the breath by the nervous, or screaming and holding of the breath on the part of frightened children. These call for common-sense treatment by encouragement and extremely chary administration. It must not be forgotten that patients have succumbed to fright before operation in pre-anæsthetic days, and that not a few fatalities have been attributed to fright and the early inhalation of chloroform. How far emotional disturbance can be justly regarded as the chief cause of these accidents is difficult to determine. It is remarkable that since anæsthetics have been in use fatalities of this kind have occurred almost entirely in connection with chloroform. If fright alone were their cause they should have happened now and again among the many thousands of times when ether and nitrous oxide and ethyl chloride have been given to terrified subjects. Yet they do not. Chloroform therefore must, we presume, play a part in those deaths which occur at the very beginning of its inhalation. We have evidence, in the occasional behaviour of persons operated on under local anæsthetics, of the part that the emotions may play. It is not very uncommon for people to grow faint or to

vomit during the performance of an operation under local analgesia while no pain is being felt. The patient will himself volunteer the statement that he feels no pain. Yet his feelings, aroused perhaps by the knowledge that he is being operated on or by vague sensations of dragging or by the sound of instruments, are such that he grows deathly pale and may actually faint.

The *spasm of muscles* often associated with complete holding of the breath which occurs after consciousness has gone in the second stage of narcosis has already been described, and is further discussed in connection with fatalities on p. 392.

Respiratory failure, partial or complete, may occur early in the third stage of narcosis. This may happen when chloroform is inhaled quietly and unconsciousness comes on without any struggling. The respiration has at first been somewhat forced, perhaps, through voluntary efforts to breathe deeply and go under quickly. A little spasm of the jaw muscles, rigidity of the arms, and raising of the body to the sitting position mark the second stage of narcosis, and these symptoms are followed by quieter breathing with relaxed repose of limbs and trunk. The pupils are now small, the corneal reflex brisk, and the colour of the face rather paler than normal. Breathing becomes infrequent and the colour of the face paler without any change in the eye appearances. The pulse declines in force in correspondence with the feeble breathing. It is as though the patient were tired with his efforts during the early stages of inhalation and his respiratory apparatus were taking a rest. On the other hand, the explanation of what we see may quite well lie at the fault of the heart and the blood pressure. The respiration may be failing because the blood pressure has fallen to a point at which the respiratory centre is insufficiently supplied, and the cause of both may be that the heart muscle is in an early stage of what would become "fibrillation" if the condition were aggravated. This state is one which arises most easily if the patient's head is too much elevated above the level of the shoulders, and that fact suggests that poor blood supply to cerebral centres may be its origin. It is a condition very often seen in children if anæsthesia is induced with chloroform. Lowering of the head, with brisk stimulation of the breathing, as by rubbing the face and lips, or with one or two compressions of the chest at expiration, rapidly restore the proper respiratory vigour.

Irregular breathing, the respirations being grouped and failing towards the end of each group, is not uncommon during chloroform narcosis. It is more often present in children than in adults, and renders safe administration difficult. For this reason it is best to substitute ether until the breathing is perfectly regular

again. This will generally be after a few breaths of ether have been inhaled. A somewhat similar spacing of the respirations sometimes occurs during abdominal operations when the recti are not fully relaxed. Generally a satisfactory condition cannot be brought about unless the operation is interrupted for a few moments while the anæsthetist stimulates respiration, lowers the head, and increases his supply of chloroform. It is not advisable to use ether unless absolutely essential, for presumably there has been some valid reason for conducting the operation under chloroform.

Restricted respiratory movements, shallow breathing with very little respiratory excursion of the abdominal wall, and this wall almost inflexible, are not infrequent during abdominal operations, and create a formidable obstacle to the surgeon's convenience. The condition is most likely to arise when operation has begun before the third stage of narcosis has been present for some time. The greatest difficulty may be met in trying to correct this form of limited breathing when it has been set up. It is started sometimes by dragging on deeply-seated structures or on the peritoneum, even when a full anæsthesia is already present. The breathing must be stimulated by lip rubbing, the freest possible airway instituted by opening the mouth and gently drawing out the tongue, and the anæsthetic given as freely as possible with safety. If the restricted movements persist, the operator must be asked to stop his manipulations during this treatment. At times a form of shallow breathing is seen under chloroform which seems to be corrected only by the addition of oxygen. A case illustrating this very well may be cited.

A thin, healthy woman of fifty underwent laparotomy for an abdominal swelling. Preliminary injections of morphia gr. $\frac{1}{6}$, atropine gr. $\frac{1}{100}$, given one hour before operation. Chloroform was used at the patient's particular request. Induction by Skinner's mask and drop-bottle was without incident, and when the third stage was present with small pupil and no corneal reflex the patient was placed in the Trendelenburg position. The abdominal muscles were well relaxed. The abdomen was opened. Forcible traction on the uterus set up very shallow breathing with steadily increasing blueness of the face. The pupil remained small and the pulse gave no cause for anxiety. The respiratory movements, however, became more and more gentle until they were imperceptible. The pulse still remained fair in quality. At my request the operation was not interrupted. The chest was compressed three times and respiration started again. It was still, however, feeble and the colour remained blue. The appendix and an ovarian cyst were removed. An oxygen cylinder had taken a little time to provide in working order (the operation was not in a hospital), but now a gentle stream of oxygen was played in under the mask. The colour of the face improved at once, and shortly after the breathing became more vigorous until, during the closing of the abdomen, it was of quite normal character under the circumstances.

In this case a reflex effect on the respiratory centre led to shallow breathing, and this to cyanosis. The cyanosis was not accompanied, as it often is, by muscular contraction or by exaggerated respiratory efforts. The way in which the circulation was maintained was probably due to the Trendelenburg position. The combination of *cyanosis and chloroform, with quiet respiratory movements,* may tend to secondary cardiac depression, and has, indeed, been responsible for some of the fatalities of chloroform. A very clear example of this combination, which only did not end fatally because detected in time, came under my notice. The cyanosis was the result of slight but long-continued mechanical obstruction to the breathing. Chloroform was not being used alone most of the time. Nevertheless the case is *à propos* here.

A sparely-built colonel, in good health except for his local trouble, was anæsthetised for a radical mastoid operation. He had morphia gr. $\frac{1}{6}$ and atropine gr. $\frac{1}{100}$ one hour before. Induction was effected with C.E. mixture, which was easily and quietly taken except for a short though strongly-marked excitement stage. A small prop was inserted between the front teeth in order to give a fulcrum for levering forward the lower jaw. The other teeth were missing, and there was no local obstruction from congested tongue or fauces. The head was turned well to the right, the left mastoid being the seat of disease, and raised a few inches above the table level. A sterilised towel covered the face and cut off the anæsthetist from the operation area. Beneath this towel the tube of a Shipway's apparatus was passed and allowed to rest just inside the mouth, being supported by the little prop. The pupil at this period was small, re-acting to light, and the colour of the face little paler than normal. Breathing was quiet with very slight obstructive stertor from the tongue. Warm ether vapour, to which from time to time chloroform vapour was added, was pumped into the mouth with each respiration. Owing to the arrangement of the towels no part of the patient's face was visible. The operation had been going on for over forty minutes, involving a good deal of work with hammer and chisel, when respiration was noticed to be irregular and considerably spaced. The blood in the operation area was seen to be blueish in colour. Lifting the towel to look at the face, one saw that the colour was dull and greyish, the pupil small and fixed, and that some perspiration rested on forehead and cheeks. The *radial pulse was imperceptible.* Pushing the jaw forward made no difference to the rate of respiration, which was abnormally slow, shallow, and irregular. The head was lowered to the level of the shoulders. The anæsthetic was withdrawn and an oxygen tube inserted in the mouth in its place. Within a few minutes the colour of the face grew pink and breathing became deeper, more frequent, and regular. Oxygen was given along with ether for the rest of the operation, which went on for another twenty minutes without any unusual incident. This case points the moral that very keen attention must be riveted on the breath sounds when the anæsthetist cannot see his patient's face. On another occasion during a long operation for glands of the neck in a child, the patient was allowed to become shocked to the very verge of death before those at work realised the gravity of her condition, mainly because the anæsthetist had no view at all of her face and was not in a position to hear the breathing distinctly.

Since the way in which the breathing is carried on is of such

vital importance to the safe inhalation of chloroform, we may appropriately insert here some general remarks on the **respiration during anæsthesia.**

The breathing of an anæsthetized person varies with a large number of altering conditions. It may almost be said that no two people breathe alike during narcosis, even if no operation is being performed. That is because there is no exact similarity in any two people of the anatomical and physiological factors of respiration. The upper air channels are narrower in one, or the pharynx congested or the larynx irritable ; in the other there is some rigidity of the chest, or some emphysema, or a natural slowness of respiration. When in addition to the natural differences there are present the variations brought about by operation, it will be readily understood that the manner of respiration offers a wide field of study. It is the more important to be familiar with these changes in breathing and to understand, as far as may be, how they come about because *the breathing is our most important guide to the general condition of the narcotized patient.* It is not possible clearly to separate the alterations in the manner of breathing which are due to the anæsthetic from those which are due to operation or other disturbance. We may, however, make some sort of classification of (1) variations in respiration during light and (2) during deep narcosis.

The factors causing these variations we shall find to be—

(1) The kind of anæsthetic and the method of administration ;

(2) Free or poor supply of air or oxygen ; too slight or excessive presence of CO_2 in the circulation ;

(3) Position in which the patient is placed ;

(4) Part of the body on which operation is performed ;

(5) Other drugs present in the patient besides the anæsthetic.

The stimulus of operation excites respiratory activity. Thus the first effect of incision is generally an increased vigour and rapidity of breathing, and the most notable change directly operation is over is a quieter form of respiration. When the operative stimulus is so long continued that exhaustion of the nerve centres comes about, then we get the feeble breathing associated with shock. The most tranquil form of breathing during general anæsthesia is seen when the respiratory passages are not involved in the intake of the anæsthetic, as, for example, in rectal anæsthesias and intra-tracheal insufflation. Over oxygenation may lead to apnœa.

The various sounds that accompany the different ways in which breathing goes on are of much help to the anæsthetist. He is enabled by ear to form a good estimate of the vigour with which respiration is being carried out, and so to appraise the

patient's general condition. These sounds may be classified as inspiratory and expiratory, according to which part of the respiratory rhythm they accompany, and, broadly speaking, it may be said that adventitious *inspiratory sounds denote deep, expiratory sounds light, narcosis.* The inspiratory sounds are mainly due to paralysis, but sometimes to spasm. Thus the loud stertor so often heard in deep ether narcosis with closed methods is due to the rumbling of the paralysed tongue and soft palate, while the high-pitched stridor evoked by stretching the sphincter ani is caused by spasmodic contraction of the glottis.

Respiratory sounds vary, apart from the effect of operation, according to the method of administration. They vary also with the various physical peculiarities of patients. The feeble and anæmic, for instance, breathe more quietly than the robust and plethoric. With open methods the respiration is quieter than when there is air limitation. It is usually of a snoring character, but in many persons it is barely audible. When the mouth is not opened by the anæsthetist, most patients breathe through the nose, and it is remarkable what efforts are made to maintain this route for the respiration, even when the nasal passages are narrow or partially blocked. The breathing may be very noisy under these circumstances, becoming at once quieter if the mouth is opened with a gag and oral breathing substituted for nasal. The common noise with inspiration is that made by the forcible sucking back of the tongue with each breath and the vibration of the soft palate. When the lower jaw is pushed well forward, carrying with it the base of the tongue, most of this sound disappears, only that part remaining which is due to the paralysed soft palate. This is the usually heard form of stertor, and is much augmented by the congestion and swelling of tongue and fauces that may occur with closed ether. The sound is not merely paralytic, for it is often present when there is obvious spasm of the muscles of the floor of the mouth and of the tongue. The characteristic stertor of nitrous oxide is a harsher sound and is differently produced, being due to irregular spasmodic elevation of the larynx. In the completely edentulous the cheeks may be sucked in with each breath, causing a soft rumble. The alar nasi in similar manner cause a sniffing sound when they are violently sucked in with each inspiration in persons whose nasal airway is deficient. We may have sounds then due to

Nose,
Cheeks and lips,
Tongue,
Soft palate,
Larynx,

and may speak, accordingly, of stertor as being buccal, labial, lingual, palatine, or laryngeal. The sounds produced in the larynx are of two kinds—a deep sound of short duration, caused by collapse, and a high-pitched longer sound, due to spasm. The latter is almost always a reflex phenomenon evoked by some part of the operation, especially dragging or stretching of sensitive structures. It is customary to speak of these laryngeal sounds as *stridor*, and when this stridor is evoked by stretching the sphincter ani it is often alluded to as the "rectal cry." The peculiar crowing stridor of children under chloroform is often the first symptom of full anæsthesia. The expiratory sounds generally accompany comparatively light degrees of narcosis, and are due to approximation of the vocal cords, being, therefore, more truly of a phonated character. They are often to be described as grunts. In the subjects of asthma expiration may be accompanied by a straining sound. In the presence of much mucus or saliva both inspiration and expiration may be accompanied by bubbling, moist sounds. These will be dissipated, as a rule, if the patient is allowed to cough. They are rarely heard now when atropine is so commonly given before anæsthetics.

The use of morphia before anæsthetics tends to render the respiration slower. Scopolamine has a similar effect. When full doses of this drug have been given the breathing may be slowed down to a dangerously few respirations per minute. This infrequent respiration lasting over a long period of time may result in defective ventilation of the bases of the lungs during the recovery period and consequent hypostatic congestion.

After-Effects of Chloroform

The usual after-effects of chloroform are slight. There are commonly some nausea and dizzy feelings, which may culminate in actual vomiting. The patient feels intensely averse from making any movement himself and is disturbed by the movements of other people. Consciousness has generally returned within half an hour unless the administration has been a very long one. The patient will go on sleeping again after the return of consciousness, and if left alone may sleep on and off for several hours. A small proportion of patients will not recover so favourably. Sickness or retching will be repeated at fairly short intervals many times during the first twelve or twenty-four hours. This commonly happens in persons who are "bad sailors" and in those with dull complexions and poor digestive powers. It is extremely unusual in those who are accustomed to free use of alcohol or of narcotic drugs. Those who have had morphia before

chloroform often start to vomit after an interval of twelve hours or so. The confirmed alcoholic rarely experiences anything more unpleasant than a headache after any anæsthetic. Generally he wakes up to full consciousness unusually quickly and demands a smoke or his favourite drink. Such persons have often described the experience of anæsthesia as "the best drunk I've had for a long time." A curious example of *amnesia* is often afforded by the patient recovering from chloroform. He wakes up, asks intelligent questions, and is apparently quite rational. Then he falls asleep again, and when he next awakes has quite forgotten all that passed when he was last conscious. Although proper preparation of the patient and correct administration of the anæsthetic play a part in avoiding sickness after chloroform, they are impotent with some individuals. The personal idiosyncrasy, whatever that unknown quality really is, exercises a dominating influence in determining the after-results of anæsthesia. Certain patients will be sick, however well they are handled, and others will recover comfortably even when the anæsthetic is given without skill or judgment.

Jaundice is an occasional sequel to chloroform anæsthesia. It may appear within the first few days or not till a week or more has elapsed. It is not of long duration, nor of serious import, unless associated with persistent vomiting (post-anæsthetic toxæmia).

Albuminuria of slight degree is not uncommon, and casts may be found in the urine. Both these symptoms are usually quickly over. This is true also of the *glycosuria* which is occasionally found. Symptoms due to lesions within the *chest* are rarely met except after long abdominal operations. Then they resemble those that follow ether, and are fully dealt with on pp. 150 *et seq.*

Bronchial irritation and spasm may be evident during convalescence when the decomposition of chloroform has gone on during the administration. The after-effects are due to the inhalation of carbonyl chloride (phosgene gas), which forms when chloroform is given in the vicinity of an open fire or gas-jet (see p. 28). Free ventilation of the room and treatment for the bronchitis are required. In these cases there may be much prostration requiring stimulants, and fatalities have occurred following the inhalation of decomposition products of chloroform.

Dryness of the mouth and *thirst* are often complained of after chloroform, but the smell and taste of the anæsthetic do not cling as they do after ether.

Delayed *chloroform poisoning*, or, as it is better termed, *post-anæsthetic toxæmia*, is an occasional sequel to chloroform anæsthesia. The condition is met after other anæsthetics also, but

it has followed chloroform more often than any other, and so may appropriately be considered here. It is described also as *acidosis* and *acid intoxication*, but, since these names and that of delayed chloroform poisoning assume an origin which is not proved, they are to be avoided in favour of the non-committal post-anæsthetic toxæmia. This after-effect of anæsthetics afflicts children much more commonly than adults. So far as I am aware, it has never occurred to any patient over fifty. The symptoms generally begin from ten to forty-eight hours after operation, before which time there is nothing to show that the course of affairs is abnormal. In one of the earliest recorded cases, however, symptoms began immediately on recovery from the anæsthetic and terminated in death nine hours later. Vomiting is the first indication that recovery is not taking place properly, for the vomiting persists and is accompanied by restlessness. The vomit consists of bile with mucus, succus entericus and gastric juice. Later there may be altered blood in the vomit and jaundice sometimes appears. The child becomes delirious, acetone is present in the urine and can often be detected in the breath, cyanosis and coma replace delirious excitement, the temperature rises, and death ensues usually within five days of the onset of symptoms. Perhaps the most remarkable feature of this disorder—a feature which almost makes one doubtful of the part that the anæsthetic plays—is the extraordinarily small amount of anæsthetic that may be concerned. Cases have been recorded when the anæsthesia has been merely due to ethyl chloride inhaled for about a minute, and several of the recorded fatalities were after short operations for tonsils and adenoids. It is difficult to reconcile these clinical facts with the experimental evidence showing that to reproduce in animals the symptoms and *post-mortem* appearances of post-anæsthetic toxæmia repeated or prolonged inhalations are alone efficient. Nevertheless, there is definite evidence that in the human being fatty degeneration of the liver, one of the chief *post mortem* appearances in post-anæsthetic toxæmia, may arise with great rapidity. Telford [1] reports the case of a woman who died of post-anæsthetic toxæmia four days after a laparotomy, during which the liver was both felt and seen. It appeared to be normal, yet at the *post-mortem* examination it was seen to be extensively affected with fatty degeneration, and this was verified by the microscope. The late Dr. Leonard Guthrie, who in 1894 was the first in this country to draw attention to the condition, believed that a pre-existing faulty state of the liver was an essential factor. He found that *post mortem* the liver of a child dying in this way was affected with intense fatty infiltration, the paren-

[1] Hewitt, *loc. cit.*, p. 639.

chyma consisting largely of oil globules and *débris* of liver cells ; the organ was of a pale buff colour. These appearances were present in five out of nine children examined.[1] Guthrie concluded that chloroform should not be given to children with fatty livers, and that the presence of this should be suspected if excess of alkaloidal substances were found in the urine. Subsequent experience has taught us that the **children who are already septic are especially likely to develop post-anæsthetic toxæmia,** and that rickety children also are more liable than others. Sepsis within the abdomen, as from suppurative or gangrenous appendicitis, is peculiarly dangerous. In these conditions, sepsis and rickets, to which may be added wasting, fatty liver is commonly present apart from any operation. The possibility of the symptoms being due entirely to sepsis or to carbolic or iodoform poisoning was discussed by Guthrie. Further experience entirely rules out the latter alternatives and makes the first highly improbable, although, as mentioned above, the presence of septic poison is undoubtedly powerful as a predisposing cause. The resemblance of the symptoms to those seen in attacks of cyclical vomiting in children has led to the supposition that the two kinds of attack may own a common origin, or that some of the cases of post-anæsthetic toxæmia may really be instances of cyclical vomiting, the occurrence of which has been precipitated by anæsthesia and operation. In the subjects of cyclical vomiting the liver is said to be fatty and the urine to contain acetone. Cyclical vomiting is, however, very rarely fatal. In some of the reported cases of post-anæsthetic toxæmia the patients are stated to have been subject previously to cyclical vomiting. The association of the symptoms with the presence of acetone or diacetic acid, or both, in the urine has favoured the idea that the attack is due to **acidosis.** Brackett Stone and Low [2] found that the amount of acetone excreted bore no relation to the severity of the toxæmia and concluded that the fatal symptoms were due to **fatty antecedents of acetone** rather than to that substance itself. Other observers have shown that acetone in small amount is commonly present in the urine after anæsthesia. Acidosis of a slight extent is known to be associated with normal anæsthesia, and the probability appears to be that excessive acidosis is an accompaniment rather than a cause of the symptoms of post-anæsthetic toxæmia. These are to be regarded as due to faulty action of the liver, which is responsible also for the acidosis. Beesly [3] believes that intoxication

[1] *Lancet*, 1894, Vol. 1, p. 193.
[2] *Boston Medical Journal*, July 7, 1903.
[3] *Brit. Med. Journal*, May 19, 1906, p. 1142.

only occurs when the kidneys fail to excrete the acetone, and that death is due to the kidneys being unable to meet abnormal demands made upon them. This observer found that both ether and chloroform always produce a temporary acetonuria. Other workers have found that acetone appears in the urine in a large proportion of children within the first few days of their stay in hospital, apart altogether from operation. It is attributed to the alteration in diet and habits involved in the change from life at home to that in hospital. Experimental work carried out by Graham [1] leads him to regard hydrochloric acid as the probable cause of the liver change found after post-chloroform toxæmia. He finds that "the central lobular liver necrosis of the type found in late chloroform poisoning is produced experimentally by other aliphatic halogen constituted compounds, viz., CH_2Cl_2, CCl, etc. It could not be produced with ether or with chloral hydrate." The necrosis depends, according to this view, on the action of the respective halogen acids formed in the breakdown of the compounds in the body—either oral or intra-portal administration of hydrochloric acid produces liver necrosis. In chloroform poisoning the central necrotic areas of the liver show a higher hydrogen and chlorine content than do control, normal livers. The formation of the halogen acid after administration of each of the drugs used is shown by the occurrence of the neutral salts of their acids in the urine.

Briefly we may say that post-anæsthetic toxæmia is a condition whose origin is still uncertain. It chiefly affects children, and especially children subject to cyclical vomiting or suffering from wasting rickets or any septic condition. Sepsis from abdominal causes is especially dangerous. Chloroform is more likely than other anæsthetics to be followed by this form of toxæmia, and the risk seems to bear little relationship to the amount of anæsthetic inhaled. Acetone and diacetic acid appear in the urine. The *post-mortem* evidence of fatty degeneration, most obvious in the liver and the kidneys, is like that found in cases of chronic septic poisoning.

The treatment for post-operative toxæmia is preventive and curative. To avoid the condition chloroform will be withheld from all patients who are especially liable in accordance with what is written above. Glucose, recommended by Beddard, has been proved to be efficacious in reducing the occurrence of acetone after anæsthesia and in diminishing the frequency of vomiting. It should be given four-hourly during the twenty-four hours preceding operation. Adults may have ounce doses, children a drachm. During this time plenty of carbohydrate food is to be

[1] *Trans. Chicago Path. Soc.*, March 1, 1915, p. 240.

allowed, and the fast before operation should not exceed four hours. When vomiting occurs twelve hours after operation, or sooner if it is unusually frequent, the stomach is to be washed out with solution of bicarbonate of soda and some of the solution left in. An enema of saline and glucose is to be given and repeated four-hourly. The quantity must bear relation to the age of the child. One ounce of glucose in 10 of saline suits children about ten years of age. The worst example of post-anæsthetic toxæmia in which I have seen recovery was that of a girl of twelve who had been operated on for gangrenous appendicitis. The vomiting had reduced her to an almost pulseless condition. She recovered after intravenous infusions of glucose and saline and washing out of the stomach with sodium bicarbonate. According to Graham alkali in proper concentration inhibits the production of liver necrosis experimentally. In practice the administration of bicarbonate of soda as a prophylactic seems less efficacious than that of glucose. Nevertheless, an alkaline mineral water may be given freely as a drink during the twenty-four hours before operation, and is probably of advantage, particularly if it contains a good proportion of calcium.

For the **treatment of less severe vomiting after chloroform** a number of drugs are recommended, but none is very effective. A drop of tincture of iodine in a teaspoonful of water taken hourly is believed in by some. Others recommend sips of iced champagne, drop doses of tincture of nux vomica, small doses of cocaine, of oxalate of cerium or of codeia, or 15 grains of chloretone. An enema of eight ounces of saline containing 15 grains of aspirin and a drachm of potassium bromide given as soon as the patient is back in bed helps many patients to a comfortable recovery from chloroform, and may quite well be given as a routine measure. Perfect quiet, gentleness in replacing the patient after operation, a sitting position, and a handkerchief moist with eau de cologne placed over the face are other routine measures that help in the avoidance of vomiting. The juice sucked from pieces of fresh pineapple is an excellent form of nourishment to allow from the first. It allays thirst and eases the unpleasant taste and dryness in the mouth. The juice of oranges or grape-fruit with sugar is also to be allowed early after operation. As Hogan [1] points out, the fruit acids are oxidised to carbonates and feeding with fruit juices represents an administration of alkali, which is beneficial. Plain water or an alkaline mineral water may be allowed to the patient in small amounts as soon as he begins to ask for anything. If this causes vomiting, or in any case, if vomiting occurs after

[1] *Amer. Year Book of Anæsthesia*, 1915, p. 175.

the first twelve hours, a glassful of tepid water containing a drachm each of sodium bicarbonate and sal volatile should be given. This often has the effect of producing an effective or final vomit. Some post-anæsthetic vomiting is probably due to mucus and saliva being swallowed when impregnated with the anæsthetic. Measures such as the above, which allow the stomach to clear itself of these fluids, are therefore of value, and are the first essential in treating the ordinary and early vomiting. Protracted vomiting after chloroform occurs without evidence of acidosis. An excellent example was the following :—

Lady T., 24, fair, healthy, lively type of woman, married, one child, had chloroform given by practitioner for repair of perineum. Operation lasted three-quarters of an hour. After recovering consciousness she vomited or retched hourly and could get no sleep. This went on for forty-two hours, when the author was asked to see the patient on account of the post-anæsthetic vomiting. Her general condition did not appear serious. Face not drawn ; pulse 80 and of good volume. The chief complaint was that "she longed to get sleep and could not on account of the vomiting." There was no smell of acetone in the breath, and there was no acetone discernible in the vomit, which was a thin, greenish, watery fluid containing bile. The urine contained traces only of diacetic acid. The stomach was washed out with sodium bicarbonate solution, a little of which was left in. An hour after this there was one vomit. The patient was asked to drink nothing except this solution (a drachm to the pint). She took half a pint during the next six hours. Small doses of egg albumen and glucose were given every two hours. That night she slept well and there was no further vomiting at all.

CHAPTER XII

ADMINISTRATION OF ETHYL CHLORIDE

ETHYL chloride is a useful anæsthetic for two purposes. It serves as an introduction to other anæsthetics, being not unpleasant or irritating to inhale and abolishing consciousness with extraordinary rapidity ; and, secondly, it provides anæsthesia for short operations, which can be completed during the narcosis provided by a single dose of the drug. Ethyl chloride may also be used in conjunction with nitrous oxide to prolong the anæsthesia. This agent is not well suited to the maintenance of a long period of narcosis. Being at once very volatile and very potent, it entails either frequent intervals of partial recovery or else a constant too profound narcosis if used for long operations. Recently M. Abrand [1] has devised an instrument which permits of a gradual and prolonged administration. He describes satisfactory results in amputations, arthrotomies and cases of hernia. Anæsthesia is maintained by about 1 c.c. per minute. A large glass ampoule contains the ethyl chloride, which issues in controlled doses by the turning of a screw-controlled mechanism. The vapour passes to a Camus mask, from which it is inhaled. Air-limitation is secured by this apparatus. The effects of ethyl chloride are intensified when it is thus given with limitation of the air supply. The power of the vapour, in fact, as with other anæsthetics, increases with its concentration. Given with unlimited air, as from an open mask, it is scarcely able to produce anæsthesia in a healthy adult. On the other hand, when used in a closed inhaler or bag, the concentrated vapour is difficult to breathe unless its strength can be mitigated at first. Hewitt made a number of experiments, at which the present writer assisted, in which ethyl chloride vapour of varying strengths was breathed through valves, the expirations escaping, just as in administrations of nitrous oxide. The results were never satisfactory. Irregular types of breathing and insufficient narcosis were the rule, even when the percentage strength of the ethyl chloride vapour was as high as 25 per cent. It was not until re-breathing was instituted that satisfactory narcosis was obtained. In these re-breathing experiments the ethyl chloride was vaporized

[1] *La Presse Medicale*, May 5, 1920.

in known quantities of fresh air in the bag. Later the bag was distended with the patient's expirations and ethyl chloride gradually introduced. In this way the best results were obtained, and this is the fashion in which closed administrations of ethyl chloride are usually practised. The percentage strength of the vapour is unknown, but it is probably well over 20 per cent.

Whether given as a preliminary or as the sole anæsthetic, ethyl chloride can be administered **either by an open or a closed method**. When an *open method* is used the liquid is sprayed on to an open mask from the hermetically sealed glass tubes in which it is provided by the makers. When using it in this way care must be taken not to send too violent a jet of spray vertically downwards to the mask. Holding the tube almost at a right angle to the mask, and with the nozzle about an inch away from it, the anæsthetist can release a spray which will not alarm the patient or cause him to hold his breath. At first the mask should not be touching the face, but after a few breaths they may be in close apposition. No accurate dosage can be attempted or is necessary when ethyl chloride is used in this way. Its extreme volatility makes it practically impossible for an overdose to be given from an open mask, so great a proportion of the amount sprayed on the mask evaporating into the air and escaping the patient altogether. At the same time, when it is used in this way for an infant, a common occurrence, too great a liberality must not be exercised. Not more than a quarter of the surface of the mask should be wetted with the spray at one time. When giving ethyl chloride to infants by the open method the anæsthetist should cause the liquid to issue, not in a spray, but by drops. This can be done by pushing a small pellet of cotton-wool under the lever which closes the outlet of the tube. Tilting the tube will then allow drops to fall. Whether drops are used or a spray, the liquid must not be concentrated on too small an area, or freezing immediately takes place. The mask should be covered with one layer of domette or a corresponding thickness of fine gauze. When used as a preliminary to chloroform, open ether, or the C.E. mixture and given on an open mask in this manner, ethyl chloride is employed merely for the sake of the rapid onset of unconsciousness which it secures. Therefore its administration is only continued for a very short time. Infants and young children are usually rendered unconscious in less than a minute, and with adults it is rarely necessary to continue with the ethyl chloride for more than twice as long. The amount that has to be used on an open mask is about 10 c.c. on the average. The *symptoms* observed are as follows. At first the breath may be held, but when it starts there is rarely coughing or any evidence

of irritation from the vapour. Some persons dislike the smell. The breathing quickens, the face flushes, and there is almost always some spasm of the jaw muscles. For this reason a prop should always be used between the teeth from the start. With the quickening respiration the pulse is also increased in frequency. The eyeballs are generally fixed and either rolled down or upwards. Usually they are turned down, only rolling upward if narcosis deepens. The pupils dilate. The conjunctival reflex disappears, the corneal remaining faintly active. The limb muscles usually are relaxed. Stertor is only occasionally caused, and should never be waited for. There is a total absence of the congestive obstruction to breathing which accompanies a full nitrous oxide narcosis, and, even when the jaw spasm leads to temporary holding of the breath, the colour of the face usually remains singularly free from blueness. When the condition of the eyes and the flaccidity of the muscles show the presence of anæsthesia, usually breathing is going on quietly without spasm, stertor, or obstruction of any kind. When given on an open mask as the sole anæsthetic, ethyl chloride can be used only for the briefest operations. Moreover, for adults it succeeds only with patients who are very susceptible to anæsthetics. It may often be used with advantage for such procedures as painful dressings, when analgesia rather than true anæsthesia is enough. For opening abscesses and similar proceedings it answers well with young children and infants.

FIG. 35.

When given from a *closed inhaler or bag* the dose of ethyl chloride must be strictly limited. For adult men the maximum single dose is 5 c.c., for women 4, and for children 3 or 2, according to their size. Various forms of closed apparatus are available. Ormsby's inhaler with the sponge removed makes an efficient apparatus. The dose is sprayed into the bag and the apparatus

applied to the face with the air-valve fully open. This is gradually closed and the bag raised. Clover's inhaler can be used quite conveniently for ethyl chloride, the amount needed being squirted into the reservoir and the small bag then placed in position. Starting with the indicator at "o," the anæsthetist rapidly advances the indicator while re-breathing goes on, the bag having first been distended with two or three expirations. Whatever inhaler is used should be of a simple nature, should allow the ethyl chloride vapour to be given gradually and breaths of air to be easily admitted, and should contain no material such as sponge or lint for absorbing the drug, since the respirations are hampered

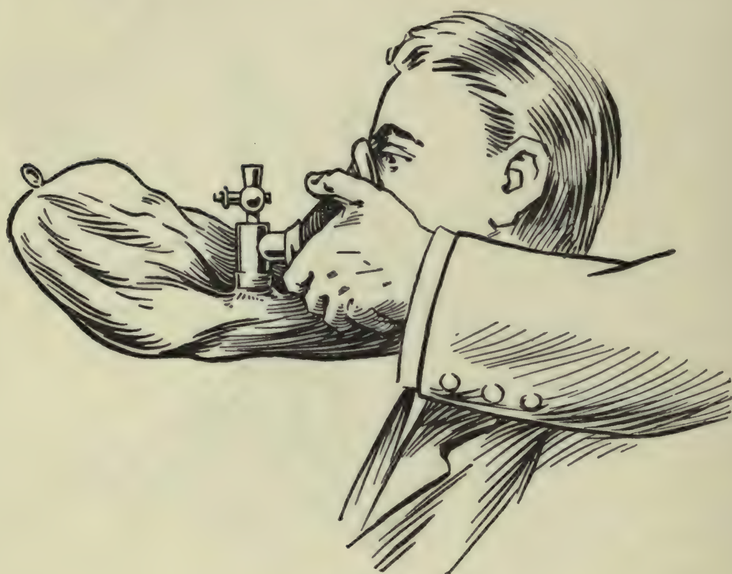


FIG. 36.

by these obstacles. The author has found the following simple contrivance quite satisfactory during its use for the past ten years (see Figs. 35 and 36).

The small bag of a Clover's inhaler is fitted on to a face-piece. The mount of the bag has a narrow limb entering it at right angles and controlled by a tap. On to this limb can be fitted a short length of rubber tube which carries a glass tube graduated to 5 c.c. The dose of ethyl chloride required is squirted into the glass tube. The rubber tube carrying the glass receptacle is fitted on to the limb of the mount, and this is so placed that the ethyl chloride remains lowermost. The tap at present is turned off. To carry out the administration the face-piece is securely applied to the patient's face, a mouth-prop being first inserted. As an inspiration is

drawn the face-piece is partly raised from the face, being lowered to catch the succeeding expiration. This manœuvre is carried out for three breaths, when the bag will be found to be fairly distended with the patient's expirations. The little tap is now turned on and the anæsthetist's hand is applied to the glass tube so that some evaporation of the contained ethyl chloride is caused by the warmth. At the same time the mount of the bag is made to revolve in its fitting to the face-piece so that the ethyl chloride assumes an upper position and flows into the bag. When the liquid has quite disappeared into the bag the anæsthetist raises this and the patient freely inspires the heavy vapour of ethyl chloride. The whole process takes place during about twelve breaths. At about the sixth breath a full inspiration of air is admitted by lifting the face-piece from the face. Two or three breaths after the moment when the bag has been held vertically up anæsthesia is present in the vast majority of cases. The *symptoms* produced are similar to those described above, but both breathing and circulation are more vigorous. More often than with the open method there is some stertorous inspiration, but the colour, though deeper than with an open mask, is very rarely cyanosed. Spasm to some degree is an almost constant phenomenon. Its severity varies, of course, widely according to the muscularity and general robustness of the individual. The red-faced, thick-set and muscular individuals display a degree of spasm rarely met with in the feeble or anæmic. Relaxation generally follows the rigidity. There may be much excitement during the first few breaths inhaled by a very muscular or an alcoholic individual. In these subjects stertor is generally loud. Unconsciousness is produced with great rapidity. A child will be unconscious sometimes after two full breaths from the bag. Owing to this rapidity and the quiet breathing and unchanged colour that often accompany anæsthesia with ethyl chloride it is easy to continue the inhalation too long. There is little doubt that in the early days of its use this happened frequently, and some of the accidents that occurred were probably due to over-dose given because the extent to which narcosis had already been produced was not appreciated.

The *available anæsthesia* obtained by a single dose given in the above described way is about a minute and a quarter after an inhalation of fifty seconds. As explained above, ethyl chloride is not well suited to prolonged administration, and the account of its clinical use here given applies only to short administrations. It has been found extremely useful, for instance, for the tonsil and adenoid operations of out-patient practice. Before applying the face-piece on these occasions a Doyen's gag is put in position.

It is important that this should be so made that the ring of the gag rests flat against the cheek and does not interfere with accurate application of the face-piece. Dr. Ll. Powell has modified the usual shape of Doyen's gag to make it meet this requirement, and the gag so constructed, in a large size, acts most efficiently with adults taking ethyl chloride from a closed inhaler for short naso-pharyngeal operations. G. A. H. Barton described an apparatus and method for prolonging the inhalation of ethyl chloride during operations on the nose and throat. The main feature of the apparatus is a metal cylinder containing the ethyl chloride which is evaporated by a hot-water jacket and conveyed along a tube to the mouth or nose. Ethyl chloride is an extremely efficient agent to employ by the closed method with patients who are bad subjects for nitrous oxide. The type of individual who becomes readily cyanosed and spasmodic with "gas" so that this is useless either as a preliminary or as the main anæsthetic, can generally be rapidly and quietly rendered unconscious by ethyl chloride.

The *after-effects* from short administrations of ethyl chloride are usually headache and sometimes vomiting. The headache is often severe, the vomiting is generally only of short duration. Either the headache or the vomiting may not begin till some hours after consciousness has returned. After quite short operations all after-effects may be absent, consciousness returning quickly and, except for a transient dizziness, the patient rapidly resuming his normal condition. This happens in about 75 per cent. of patients who have had only short inhalations of ethyl chloride. After longer operations the proportion of people who suffer after-effects is considerably higher. Moreover, after the longer inhalations there is often a degree of prostration that requires treatment. The patient must be kept horizontal and stimulants may be needed. No doubt the condition is due to the lowering effect that ethyl chloride has on the blood pressure. In over 5,000 administrations of ethyl chloride by a closed single-dose method for short throat operations at St. George's Hospital three patients only have needed treatment for symptoms attributable to the anæsthetic. In the three cases circulatory depression after operation was the symptom that called for correction, and horizontal posture with brisk rubbing of face and lips was all that was necessary. Dale reports 20,000 similar cases without death and "with the rarest occasion for anxiety."

The *dangers* that may arise in practice are due to *over-dosage* or to *respiratory interruption with spasm*. In the patient who has received an over-dose the danger is due to the power of ethyl chloride to lower blood pressure. Pallor, widely dilated pupils,

feeble pulse, and faint breathing are the symptoms, and they may appear with suddenness. Lowering of the head with firm pressure on the abdomen while the chest is rhythmically compressed is the treatment to be immediately applied. This kind of danger is scarcely ever met with during the open administration of ethyl chloride. *Stoppage of the breathing*, with spasm, the second source of danger, may be brought about by an inhalation of ethyl chloride which is not excessive in quantity. We have seen that the drug very readily causes spasm even when inhaled in properly diluted vapour. In certain individuals this spasm may affect the muscles of the jaw and of the tongue to a degree which makes the local obstruction to breathing complete. With teeth tightly locked and tongue spasmodically retracted the patient has no patent airway through which respiration can be carried on. The mouth must be opened, the tongue drawn forward, and the chest compressed. This treatment, promptly applied, quickly restores normal breathing. Should the condition be allowed to arise, however, in a patient whose heart is weak or diseased, secondary heart failure may follow with fatal consequences. This spasmodic arrest of breathing rarely causes serious trouble if the mouth is propped open before the inhalation is begun.

The *safety* of ethyl chloride has been very differently estimated by different authorities. Figures have been given above showing how safe it may be for short operations. McCardie reckoned the mortality to be about 1 in 3,000; other authorities estimate it at 1 in 7,000.[1] It is commonly regarded as being less dangerous than chloroform, and more so than ether.

[1] Hewitt, *loc. cit.*, p. 456.

CHAPTER XIII

MIXTURES AND COMBINATIONS OF ANÆSTHETICS

THE anæsthetics the use of which individually we have now described are also frequently employed in various mixtures and combinations. By mixture we mean that the agents are mixed in definite proportions before use, by combination that they are employed one following on or in addition to another. Thus many short operations on healthy persons are conveniently performed with an anæsthesia produced by the use of nitrous oxide followed by ether; long operations not requiring extreme relaxation are suited by gas and oxygen with more or less ether added, and a mixture of chloroform and ether (C.E.) provides what is perhaps the most useful all-round anæsthetic for abdominal operations. Ethyl chloride is often used as an introduction to ether and sometimes to chloroform. Furthermore, local and spinal anæsthetics are often most advantageously employed in co-operation with general anæsthesia.

Mixtures may consist of an anæsthetic with some other substance which is not itself an anæsthetic. Chloroform is often given, for example, mixed with alcohol, and the familiar A.C.E. mixture consists of chloroform, ether, and alcohol. Mixtures have been objected to on the ground that, the constituents of the mixture having different rates of evaporation, the vapour inhaled will not represent the proportions of the liquids mixed. The more volatile constituent will evaporate from the mixture more rapidly than the less, and consequently at first will provide a large proportion of the inhaled vapour, while later on the less volatile constituent will provide the chief part of the vapour inhaled. This objection, though theoretically correct, is not of practical importance if the mixtures are given by an open method and if only such small amounts are constantly placed on the mask as can be rapidly and entirely vaporized. In this way, for instance, mixtures of chloroform and ether are frequently used with excellent effect. If, however, the mixtures were used from closed inhalers in which large quantities were inserted, the different volatility of the two ingredients would no doubt come into play, and at first the patient would inhale a vapour which was mainly ether, to be followed later by one which was almost entirely

chloroform. The first rule in practice, therefore, regarding mixtures containing chloroform is that they should be given by an open method and by frequent provision of small amounts of the mixture. It is true that of recent years this rule has been frequently broken without apparent harm. Mixtures of ether and chloroform have been used from Clover's inhaler. The proportions of chloroform in these mixtures have, however, been very small, and to this fact is probably due the safe use of the method. Moreover, the method was introduced for, and has been restricted to, subjects of the robust type ; it started, in fact, in military practice. McCardie,[1] working with a wide-bore Clover's inhaler (Hewitt's modification), tried various proportions of chloroform to ether in order to avoid the coughing that he met frequently in the induction of anæsthesia in soldiers, and in order to get more rapid and complete muscular relaxation. He found that the proportions of one of chloroform to four, to seven and to eight of ether (by volume) gave mixtures which were dangerous and led to blueness of the patient with depression of the breathing. On the other hand, thirty-two parts of ether to one of chloroform provided a mixture in which the chloroform effect was negligible. Sixteen of ether to one of chloroform gave a mixture which could be safely used from the Hewitt's inhaler and in 1,200 cases provided very satisfactory results. Induction was quieter than with ether alone. "The addition of this small amount of chloroform seems to make a very great and advantageous difference." The mixture is used exactly as if it were ether, but breaths of air are admitted more freely during induction than is the general practice when ether alone is employed for robust subjects. In my own experience a mixture of one part of chloroform to twelve of ether used in this manner from a Hewitt's inhaler gives excellent results with difficult subjects. Great care is to be taken to avoid cyanosis, and the administrator must constantly bear in mind the presence of chloroform in his closed inhaler. When anæsthesia is reached he will generally be wise to keep the bag off or to give breaths of air at very frequent intervals. McCardie recommends that twenty drops of a mixture of two parts ether to one of chloroform should be put into the bag for beginning the administration. Silk [2] was of opinion that chloroform and ether in the proportions of 1 drachm to 2 ounces, McCardie's one to sixteen, may be used by the open method throughout in place of pure open ether. Later [3] this observer arrived at the proportions of one chloroform to thirty-two ether as correct for administering

[1] *Brit. Med. Journal*, April 21, 1917.
[2] *Proc. Royal Soc. Med.*, Vol. 11, No. 2 (Anæsthetic Section).
[3] *Brit. Med. Journ.*, May 24, 1919, p. 636.

the mixture exactly in the same way as open ether, with face-pad and thick mask. Various workers have, in fact, used various small proportions of chloroform on the mask in addition to ether when given by the open method.

The *chief chloroform-containing mixtures* in common use are—(1) the C.E. mixture ; (2) the A.C.E. mixture—one part alcohol, two chloroform, three ether ; (3) the Vienna mixture—one part of chloroform to three of ether ; (4) Billroth's mixture—one part alcohol, three chloroform, one ether ; (5) chloroform and absolute alcohol—nine parts chloroform to one part absolute alcohol. The use of alcohol with chloroform is not merely for the purpose of diluting the vapour. It has been shown that the fall of blood pressure ordinarily present during chloroform anæsthesia is largely prevented by the absolute alcohol, and that respiration is less depressed than by chloroform alone.[1] The A.C.E. mixture was favourably reported on and recommended as preferable to chloroform by the Committee of the Royal Medical and Chirurgical Society. It has been very widely employed. With the methods at present in vogue for giving these mixtures, there is, however, no apparent advantage in the presence of the alcohol, and A.C.E. has largely been replaced by the C.E. mixture. This we may regard as the typical chloroform-containing mixture, and we may therefore go into some details as regarding its administration and effects. The general principles that guide us in the use of the C.E. mixture apply to all the other chloroform-containing mixtures. In conjunction with the late Sir Frederic Hewitt the present writer investigated the properties of C.E. mixture as a routine anæsthetic for a large variety of patients and operations.[2]

Method and Apparatus.—The mask consists of a wire frame over which is stretched a single layer of flannel. It presents an oval opening 5 inches by 3 and is capable of close adaptation to the face. The vault of the mask is high enough not to touch the nose when the rim rests on the face. The size of the mask and the material with which it is covered are important details. For instance, if two layers of flannel are used instead of one the same quantity of anæsthetic produces different effects in the two cases. For robust or alcoholic subjects the present writer prefers two layers of domette to one of flannel and uses a Schimmelbusch frame with guttered rim. In using the mixture a gradual process is followed. The mask is applied near to, but not touching, the face, and the mixture is added a few drops at a time. A drop-bottle is used capable of delivering isolated drops, a rapid series of drops, and a continuous stream. During the first two minutes the mixture is added in quantities so small that not more than a quarter of the mask is moist at the same time. By the end of two minutes the mask is resting over the face, and the mixture is now applied with greater freedom. At the end of four minutes the whole surface of the

[1] *Trans. Roy. Soc. Edin.*, Vol. 41, Part 2, No. 12.
[2] *Lancet*, July 3, 1909, pp. 10 *et seq.*

mask is moist with the liquid. For robust subjects and for men, as a rule, this degree of wetting the mask is maintained till full anæsthesia is present, and often for some time after that. For women, as a rule, about three-quarters of the mask surface should be wet, and for children one-half.

Time required for inducing Anæsthesia and Symptoms evoked.—The time of induction is reckoned from the beginning of inhalation to the moment when the patient is ready for operation. This was determined by—(1) absent corneal reflex; (2) complete muscular relaxation; (3) inspiratory stertor. The average induction period in a series of hospital cases was eight and a half minutes. The longest was seventeen minutes, and the shortest five. Children were generally ready in five minutes, and feeble women often. The vapour is not commonly found objectionable or irritating. Excited talking becoming incoherent or quiet, busy muttering occurred in one-quarter of the hospital patients. Excited movements of limbs or trunk requiring restraint occurred in one of forty patients. Excitement, when it arose, was always after consciousness had disappeared. Secretion of mucus and saliva is not a noticeable feature.

Amount of Mixture used.—The average amount required in a long series of patients was 1 ounce in fourteen minutes ; the least used was ½ ounce in twenty-two minutes for a feeble infant, and the greatest quantity was 3¼ ounces in thirty minutes for a fat alcoholic woman. When anæsthesia has been established it is not generally necessary to keep more than one half of the mask moist, even for men. Women and children often have the mask only half moist during induction and one-quarter moist for the rest of the time.

The Condition of the Patient.—A highly satisfactory state of the circulation and respiration with complete relaxation of muscles and immobility of the patient can invariably be obtained. Respiration is more vigorous, the pulse quicker, and the colour fuller than in the average patient under chloroform. The pupil is usually slightly larger than that seen in *safe* chloroform anæsthesia. The type of anæsthesia more nearly resembles that of low chloroform percentage than that obtained by pure ether. Serious disturbances of pulse or breathing, reflex effects of operative activity, are, however, distinctly less liable to arise during the anæsthesia due to C.E. mixture than during that due to chloroform. Reflex movement of limbs or rigidity of muscle were very rarely met with, and this absence was particularly noticeable in rectal operations, which under ether are often attended by these reflexes. Severe surgical shock resulting in disappearance of pulse, dilatation of pupils, opening of eyes, pallor and stopping of the breathing, was seen in one thin, anæmic

woman on whom laparotomy was being performed. The corneal reflex was just present at the moment when the shock symptoms were suddenly presented.

After-effects.—In no patient in a series of 300 were there severe after-effects. Generally after twenty-four hours there were no symptoms referable to the anæsthetic. In several patients there was vomiting once or more often after recovery of consciousness. After-effects from C.E. mixture are less common, in the writer's experience, than from any other anæsthetic except pure gas and oxygen. The anæsthesia obtained from C.E. mixture may be regarded as that of a diluted chloroform vapour, which physiologically it closely resembles. Yet in practice this anæsthetic presents great advantages. It is safer in the hands of the inexpert than any method of giving chloroform alone, it has a wider range of applicability than any other equally safe agent, and it is not followed by the serious toxic effects occasionally seen after chloroform, nor by the respiratory complications that may be due to ether. Although the physiologist regards the ether in the mixture as simply a diluent of the chloroform, yet clinical results suggest that it exerts on the human subject a stimulating influence of its own and in this respect allows us to do without the absolute alcohol of the A.C.E. mixture. The latter and the other chloroform-containing mixtures mentioned above are to be given on the lines laid down for the C.E. mixture. In using the chloroform and alcohol mixtures some anæsthetists prefer to employ Junker's inhaler. When any of the mixtures are employed for feeble subjects or for very severe operations oxygen may with advantage be used in conjunction with them. The methods of employing it in this conjunction are the same as those described in connection with chloroform.

Anæsthol is a mixture of chloroform, ether, and ethyl chloride which has been largely used in America. It is declared to be a chemical combination, not simply a mixture. The proportions present are 83 per cent. by volume of chloroform and ether to 17 per cent. by volume of ethyl chloride. The chloroform and ether are mixed in the proportions of 43·25 chloroform to 56·75 ether by volume, and of this mixture, which is held to be a stable molecular solution, 83 volumes per cent. are taken to 17 of ethyl chloride. Anæsthol is administered with free air dilution according to the rules laid down for the other chloroform-containing mixtures. It produces anæsthesia more quickly than most of these, which may be due to the large proportion of ethyl chloride which it contains. In other respects the symptoms accompanying its inhalation are very like those produced by C.E. mixture.

Combinations of Anæsthetics

The chief combinations to be considered are—

(1) Nitrous oxide and ether ("gas and ether"); gas and ether followed by chloroform.
(2) Nitrous oxide and oxygen with ether or C.E. mixture.
(3) Ethyl chloride and ether, ethyl chloride and C.E. or chloroform, ethyl chloride and nitrous oxide.
(4) Chloroform and ether given one after the other.
(5) Local anæsthetics or spinal anæsthetics combined with general anæsthesia.

Preliminary narcotics are often used before combinations of anæsthetics just as they are before anæsthetics used individually. Patients may, it will be seen, be submitted to a considerable variety of drugs and methods for a single operation. A hypodermic injection of mixed narcotics may be followed by an intra-spinal injection of stovaine, which is followed by an inhalation of nitrous oxide and oxygen, or perhaps of C.E. mixture or open ether. This is a wide departure from the simple administration of one anæsthetic agent, as in earlier days, but the anæsthetist is enabled by having these different measures at his disposal to use them in such combination that he can ensure a good result for almost every kind of patient or of operation. The perfectly simple measures, on the other hand, will often leave much to be desired, whether during induction, operation, or the period of recovery. It is part of the anæsthetist's work to detect the factors which would prevent complete success under simple measures, and when these factors are present to adopt the various means at his disposal to counteract them. Thus he uses his preliminary narcotics to quiet the highly nervous, his spinal injections to ensure absolutely relaxed muscles in those to whom chloroform or ether could not safely be given to the necessary extent, and he employs gas and oxygen to avoid after-sickness when this has proved itself a formidable obstacle to the patient on a previous occasion.

"Gas and Ether"

This combination of anæsthetics has many advantages and was until recently very widely employed. The open method and the use of continuous nitrous oxide and oxygen have largely diminished its popularity, but there is still a large field in which "gas and ether" may justifiably be selected. For short operations on healthy persons who prefer to be made unconscious quickly it is unrivalled. It is particularly applicable when a deep narcosis is required under these circumstances, as, for example, in many

rectal operations. Nitrous oxide is an excellent introduction to ether because of its tastelessness, its rapid action, and the fact that the air-limitation which accompanies its use can be continued during the early stages of ether inhalation. Thus properly employed, " gas and ether " permits the patient to be put fully under ether without his tasting the second drug at all until the return of consciousness. Clover, who originally introduced this plan of anæsthesia, at first used to get the patient fully under nitrous oxide and then change to an ether inhaler. Later he started with nitrous oxide and then added ether gradually by passing the gas over it. It is perfectly possible in many subjects to secure a full nitrous oxide anæsthesia and then, doing away with the gas altogether, to apply ether so freely that a full ether narcosis follows on without any interval of returned consciousness. Some anæsthetists still follow this line. Better results, however, are seen if the ether is gradually admitted, nitrous oxide being used first to the point of abolishing consciousness and then being readmitted as required if ether narcosis comes on too slowly. Clover designed and used a special apparatus for the administration of nitrous oxide and ether. Largely owing to the work of Hewitt, however, it has been shown that perfect results can be obtained by using the portable ether inhaler in conjunction with the nitrous oxide apparatus described on p. 158. No special apparatus is therefore required, the bag connected with the gas cylinders is fitted on to the top of a wide-bore inhaler, the face-piece carefully adjusted, the head rested on one side, and the administration started just as though the patient were about to inhale ether. No ether, however, is at present in the apparatus. The opening for inserting it faces upwards, so that ether is easily poured in later, and is, in fact, not put into the inhaler until the patient is unconscious with nitrous oxide. At the beginning of the administration the gas-bag is filled about two-thirds full before the face-piece is applied. The ether indicator is at " 0," the expiratory valve open, and the stopcock is off, so that when the face-piece is applied and the bag fitted on to the inhaler the patient merely breathes air through the apparatus. The stopcock (H) is then turned on and nitrous oxide is breathed in and expired through the expiratory valve. With the foot allow gas to enter the bag gently from the cylinders, replacing the inspired gas. After six breaths of gas have been inhaled and the expirations allowed to escape, pour 1½ ounces of ether into the inhaler, replace the stopper, and gently start turning on the ether indicator. Gas is still being allowed to enter the bag from the cylinders and the expirations to escape. Now when about eight or ten breaths of gas have been breathed through valves close the

expiratory valve. The indicator has been slowly but continuously advanced, and is now at "2." Open the stopcock for a breath, so as to admit one breath of air. When it is closed again the patient is re-breathing a mixture of nitrous oxide, ether, and residual air. The indicator is now advanced more rapidly and reaches "F" within about four minutes from the start of the administration. By this time full narcosis is present, with stertorous breathing, relaxed limbs, and dusky face. Open the expiratory valve, allowing expirations to escape and the bag to become emptied. Replace the gas-bag with the simple small bag of the ether inhaler and continue exactly as though ether had been used alone throughout. Naturally the exact moment for carrying out the various little actions here described is different with different patients, and practice alone enables the administrator to achieve perfectly smooth inductions.

The most important points to attend to are—

(1) Do not introduce the ether too soon, or one of the chief advantages of the method is lost—viz., freedom on the patient's part from all knowledge of ether inhalation.

(2) On the other hand, nitrous oxide must not be given to the point of jactitation; breaths of air must be admitted freely in order to avoid reaching this extreme and to avoid too great cyanosis. The admission of air will be sooner and more frequent the feebler the patient. Robust individuals will necessarily become slightly cyanosed before anæsthesia is reached. This blueness must be completely got rid of by the time that the gas-bag is removed.

(3) Do not take off the gas-bag until you are sure that the patient is really under ether. It is easy to be deceived by an anæsthesia which is still largely due to nitrous oxide. If under the impression that the patient is ready operation is then begun, recovery from the nitrous oxide may occur before full narcosis from ether is yet present, and inconvenient movements will arise. By delay in getting rid of the gas-bag during induction any symptoms of recovery from nitrous oxide and still incomplete ether narcosis—movements, coughing, etc.—can be at once abolished by closing the stopcock and readmitting a breath or two of "gas." The anæsthetist, in fact, feels his way, so to speak, as to when to get rid of his nitrous oxide. He remembers that the advantages of this in the method are solely those of an introduction. The sooner the gas can be got rid of without any knowledge on the part of the patient, and while he breathes ether vapour freely, the more smoothly will the induction proceed.

(4) The face-piece must fit accurately, so that no air is inhaled

round the edge. A *simpler way of using "gas and ether"* is to do without the gas-bag with its valved stopcock and merely use a tap which allows gas to enter the small bag of the inhaler straight from the cylinders (Fig. 35). When this device is relied upon re-breathing takes place from the beginning, breaths of air are admitted merely by occasional raising of the face-piece, and the process, though very effective, does not allow induction, as a rule, to be so quiet or accompanied by so good a colour as is commonly achieved by using the valved stopcock. The apparatus above described (wide-bore Clover with gas-bag and cylinders) permits of the use of nitrous oxide and ether in the manner which the present writer has described as "new gas and ether." [1] By this is denoted a method in which nitrous oxide is relied on throughout, ether playing the supplementary part, instead of, as in the "old" method, gas being merely preliminary, while the maintenance of anæsthesia depends entirely on ether. A large number of operations can be performed during the anæsthesia, which is little more than that of nitrous oxide, and the patients are proportionately benefited by their freedom from discomfort afterwards. This anæsthesia is employed in the method here alluded to instead of full ether narcosis of the older method. The author had, with many other anæsthetists, long since realised and used for short operations the anæsthesia produced by nitrous oxide aided by a little ether. It was the many long operations on the limbs of war patients that led him to realise the possibility of considerably extending the use of this kind of anæsthesia, an anæsthesia which is throughout truly a gas and ether narcosis, but more of "gas" than of "ether." Induction takes place exactly as described for "gas and ether," but when full anæsthesia is present, instead of getting rid of the gas, as in the old method, the anæsthetist's aim is to use the nitrous oxide all the time and the ether as little as possible. If the patient is a difficult subject, let the indicator be advanced quite to "Full" in the course of induction. When anæsthesia is reached, turn the indicator rapidly back to "o." Open the expiratory valve, thus emptying the bag, and at once refill it two-thirds full with nitrous oxide, which gas allow to be re-breathed. Give breaths of air as often as necessary to keep the face free from blueness. Empty the bag, by opening the expiratory valve, about every five minutes. Any indication that the narcosis is too light is met by advancing the indicator and admitting a breath or two of ether. An oxygen cylinder can easily be connected with the bag, using at its distal end a V-piece, one limb of which connects with an oxygen and the other with a

[1] *Lancet*, Jan. 31, 1920.

nitrous oxide cylinder. The comparatively simple apparatus thus provided permits of quite good results in long "gas and oxygen and ether" cases.

Nitrous oxide and ether followed by chloroform provides a combination which is often used with advantage. The object of this particular alliance is to secure the rapid and safe induction of "gas and ether" for patients in whom it is desired to perform the operation under a chloroform anæsthesia. Persons who are extremely susceptible to the taste and smell of ether and are nauseated for long periods after ether inhalation should not be given this combination. With them even the short ether inhalation involved in this combination is enough to produce the unpleasant after-effects. For others the combination acts very well. It is important that the change to chloroform is made just at the right point of time. This is when consciousness has been completely abolished, when ether has been inhaled for a few minutes, and when respiration has become regular and unobstructed. The corneal reflex should not yet have disappeared and there should be an occasional slight effort at coughing or swallowing. The "gas and ether" having been given as described above, the apparatus is now discarded and replaced by drop-bottle and open mask, Junker or Vernon-Harcourt inhaler, as the anæsthetist wishes. He starts the chloroform gradually, taking particular care not to let it be too freely inhaled while the vigorous breathing of ether narcosis is still in being. He pays also particular care to complete absence of cyanosis by the time that the chloroform is being given in more than the smallest doses. Before the advent of open ether this method was freely used for abdominal work, the chloroform being administered to a full degree. There is little doubt, however, that a better result is eventually achieved by employing an open method from the start. More time is needed, but the ultimate result, particularly as regards relaxation of muscles and quietude of breathing, is better. Nevertheless it must be said that many competent anæsthetists still employ this nitrous oxide-ether-chloroform combination or precede C.E. by nitrous oxide and ether or ethyl chloride and ether. Some, indeed, precede open ether by nitrous oxide, ether, or ethyl chloride and ether in closed inhalers merely to gain the short induction. All these procedures may give quite satisfactory results; but when, as in abdominal operations or operations about the face and nose and throat, quiet breathing and freedom from congestion are all-important, then these closed preliminaries should be avoided. Before the advent of open ether and of warmed ether vapour we had practically only chloroform to rely upon for the best results with abdominal and with throat work. Consequently we were

led to these combinations in order to avoid as far as possible risks with this drug and to gain the advantage of having the patient, so to speak, charged up with ether and benefited by its circulatory and respiratory stimulation before deep chloroform narcosis was brought on. More modern methods and appliances enable us to obtain the requisite anæsthesia and lack of congestion with ether alone, or aided by small amounts of C.E. mixture. The older combinations are therefore less often to be selected.

Nitrous Oxide and Oxygen with Ether or C.E. Mixture

All the apparatus for continuous administration of nitrous oxide and oxygen allows, as we have seen (p. 179), the passage of the gases through a bottle in which may be placed a quantity of ether or of C.E. mixture. Except for very difficult subjects, ether alone should be present. In connection with the use of ether along with "gas and oxygen" we must bear this in mind, that re-breathing plays a prominent part in this mode of anæsthesia, and that consequently, even if we admit ether for only a few breaths, it may be retained in the patient's body for a considerable period. Thus it behoves us, if we want to reap the full benefit of a nitrous oxide-oxygen anæsthesia, to avoid all use of ether and leave the patient afterwards taste-free and without sickness. Very often indeed, however, particularly when the method is used for abdominal work, a certain amount of ether is indispensable. When the anæsthetist feels sure that he will need its aid he acts wisely to begin the use of ether during induction. The reason for this is that it is difficult with the apparatus (Boyle's, Shipway's, etc.) rapidly to produce a full ether effect. Consequently, if in the course of an operation under gas and oxygen the need for a deeper anæsthesia than these gases can give suddenly arises, the anæsthetist requires some little time before he can meet the surgeon's requirements. If, however, in the course of induction, after all sensibility to the taste and smell of ether has been obliterated by nitrous oxide and oxygen, he passes these gases through his ether for a few minutes, then by the time full anæsthesia is reached the patient is in a state in which he can not only be kept well under with the gas and oxygen alone, but also, if deeper anæsthesia is needed, he can quickly be put deeply under by readmission of ether for a few breaths. We have seen that a chief secret of success with continuous gas and oxygen is keeping the patient free from the least cyanosis. Rather, then, than increase the proportion of nitrous oxide to the point of blueness in order to get anæsthesia in a difficult subject, introduce enough ether to permit full narcosis

with a pink complexion. Where subjects of the most resistant type are treated by "gas and oxygen" for abdominal operations it may be necessary to replace the ether by C.E. mixture and to use it in the way just indicated. A purely gas and oxygen narcosis may suffice for opening the abdomen, but may prove quite insufficient when the peritoneum is pulled on or viscera are dragged. It is wise, therefore, in all but the easiest subjects to introduce ether or C.E. into the circulation before the abdomen is opened.

Ethyl Chloride and Ether

Ethyl chloride provides a useful introduction to ether given by the closed method for those patients for whom nitrous oxide is ill adapted. We have seen that spasm and cyanosis are extremely apt to interfere with a quiet induction by means of nitrous oxide when this is given to the plethoric, very fat, or alcoholic patient. These people can, however, be commonly rendered unconscious with ease and great rapidity by the use of ethyl chloride. Experience has shown, moreover, that, followed immediately by ether, ethyl chloride can be used with safety in the manner to be described. A wide-bore Clover's inhaler, the small bag of which is fitted with the tap shown in Fig. 35, is all the apparatus necessary. An ounce and a half to two ounces of ether must be placed in the inhaler before the administration is begun, care being taken, however, to blow away all traces of ether vapour (see p. 121). Through the tap 5 c.c. of ethyl chloride are then squirted into the bag, and during an expiration the face-piece is applied. Preliminary arrangements of prop, etc., must be as for administration of ethyl chloride alone (p. 221). During the first two breaths after the face-piece has been applied this is raised during inspiration and pressed to the face during expiration, so that the small bag becomes well distended and the ethyl chloride in it properly vaporized. For the next three breaths the patient re-breathes ethyl chloride vapour, and then the indicator is turned to admit ether. This can now be admitted in rapidly increasing amount, the quick action of the ethyl chloride having rendered the patient insensible, and within three minutes the indicator reaches "Full," the patient is re-breathing a strong ether vapour, the small bag is taken off and pressed empty, replaced on the inhaler, and matters are conducted as though the administration were one of ether from the outset. When ethyl chloride is used in this manner the dosage must be regulated just as was done for its use alone from a closed bag (see p. 121). Occasionally a nervous patient will desire above all things to be rendered unconscious quickly. When the operation is one for which ether can suitably be

employed the process just described is most suitable. The dose can be given more accurately and the admission of ethyl chloride can be made more gradual by fitting on to the tap of the bag the little graduated glass tube with rubber attachment described for the administration of ethyl chloride alone (p. 222). The process there detailed is to be carried out, ether, however, being added in the way that we have just described. The admission of early breaths of air must be allowed when this preliminary use of ethyl chloride is practised before closed ether. Cyanosis should not be a marked feature of the induction. The method is best employed upon patients with sound circulatory and respiratory systems, and should be avoided with weakly and anæmic subjects. *Ethyl chloride sprayed on an open mask* is often a most useful introduction to the use of C.E. mixture or open ether for a frightened, crying child. The amount that can be safely used on an open mask not too closely applied is almost indefinite, owing to the extreme volatility of the liquid and the freedom with which it consequently evaporates into the air. When using ethyl chloride in this way the anæsthetist does not aim at obtaining full anæsthesia with it, but merely an insensibility sufficiently deep to allow of the free application of the agent on which he is going to rely during the operation. Ethyl chloride is often thus used before chloroform, but the procedure may easily become dangerous. If anæsthesia is to be reached through chloroform before the insensibility due to ethyl chloride has passed off, dangerously large amounts of the former drug may have to be rapidly inhaled. The lowering effect of ethyl chloride on blood pressure renders such a proceeding inadvisable. G. A. H. Barton recommends, and has frequently employed, a somewhat complicated combination of C.E. mixture, ethyl chloride, and ether. His object in starting with C.E. mixture is "to ensure that there is no gap between the fleeting anæsthesia of ethyl chloride and the permanent one of ether." The quantity used varies, of course, with the age and physique of the patient. Barton mentions 20 minims for an infant, and 4 drachms for a lusty young adult. After the C.E. has been given on the open mask, ethyl chloride is sprayed on and the mask enclosed within a towel. Full anæsthesia is thus obtained, and then the mask is removed and the ether inhaler applied.[1] Preliminary alkaloids are used. Barton also recommends a C.E.-ethyl chloride-chloroform combination, but there are, as pointed out above, obvious objections to following ethyl chloride directly by chloroform. Ethyl chloride has been used to prolong the anæsthesia of nitrous oxide for dental operations. This object can certainly be achieved,

[1] "Backwaters of Lethe," p. 68.

but very often at the expense of a subsequent headache on the patient's part. Generally speaking, it is better to use nasal methods, or else a full "gas and ether" anæsthesia, according to the type of patient, when a longer time is needed for tooth extractions than can be got by an oral administration of gas and oxygen. However, occasions do arise when it is most convenient to provide a minute or two of available anæsthesia by the use of nitrous oxide and ethyl chloride. The method employed is as follows. Fill the "gas-bag" of Fig. 20 with about 3 gallons of nitrous oxide. Disconnect it from the tube and the cylinders and turn off the tap at its lower end. Fit on at the lower end the short rubber tube attached to small graduated glass tube containing the dose of ethyl chloride. Now apply the face-piece, and after four breaths of nitrous oxide have been inspired, with expirations escaping, close the expiratory valve. Turn on tap (E) and tilt the ethyl chloride gradually into the bag so that the patient breathes to and fro the mixed vapours. Give breaths of air as required by the colour of the face or the character of the breathing. It is not generally advisable to use more than 3 or 4 c.c. of ethyl chloride. Do not allow marked duskiness of the face or loud stertor. Complete the administration by opening the expiratory valve and allowing the bag to be nearly emptied.

Chloroform followed by Ether

We have seen that during the induction of anæsthesia by chloroform some administrators practise the use of ether during the second stage when there is much spasm or holding of the breath. It is thought that the stimulating qualities of ether ensure a safe passage for the patient through that period of narcosis when the heart is liable to sudden failure during chloroform inhalation. Similarly, when a patient is fully under chloroform it is not infrequent for a change to be made to open ether. This is generally done with the idea of providing greater safety, and is frequently practised during long, severe operations or during operations on feeble subjects. Occasionally when there is difficulty in securing complete relaxation of the abdominal muscles during chloroform narcosis, even though the chloroform is given to the limits of safety, the relaxation can be brought about by substituting ether and giving this to the fullest extent. The eventual power of relaxing muscles appears to be greater in ether than in chloroform. Again, sometimes the crowing respiration associated with intra-laryngeal spasm arising reflexly during chloroform inhalation can be got rid of by replacing the chloroform

with ether. Very small amounts of chloroform from an open mask are often used, because of the less irritating effect of the drug, to start an anæsthesia which is to be maintained by ether, and when closed ether is to be used this procedure is often convenient if the patient fears the close application of a face-piece. At the same time it must be remembered that it is exactly in the induction of anæsthesia that chloroform is most to be dreaded, and therefore if it is used in this preliminary fashion, it must not be pushed beyond the first stage. That is to say, as soon as consciousness is gone, or even sufficiently blurred, the ether is to be applied and persisted with. In this way if any excitement stage arises it will be during the inhalation of ether, and not of chloroform. The administration is begun exactly as though it were to be conducted with chloroform throughout. The patient is encouraged to breathe freely while the open mask is held quite near to, but not touching, his face, and a slow but continuous series of drops is allowed to fall. The rate of dropping is steadily increased, and within two or three minutes the ether can be gradually substituted either by the open method or by a Clover's inhaler without the patient realizing or resenting the change. The ether vapour first applied must not be too strong. If the Clover is used the indicator should be at "1" when the inhaler is first applied. Then, no coughing or swallowing being excited, the strength of vapour can be rapidly advanced.

Chloroform, C.E., and Ether in Combination

The use of *C.E. mixture* between chloroform and ether is practised by some. The procedure is exactly similar to that just described, but instead of giving way directly to ether the chloroform is followed on the open mask by free administration of C.E. mixture, and a full anæsthesia is obtained with this before ether is substituted. When anæsthesia is reached the more thickly covered mask (p. 109) and the face-pad are put into use and open ether freely given. This combination of anæsthetics is very suitable for robust subjects with whom the operation is to be conducted under open ether. The induction is pleasant and not nearly so prolonged as if ether is used from the start. If there is much excitement or spasm during the C.E. inhalation period, then the change to ether is made at once without awaiting anæsthesia. During this period of excitement the patient is never conscious, and consequently a strong ether vapour can be imposed without causing discomfort. Preliminary hypodermics are to be used just as before simple open ether.

Ether followed by Chloroform

Although this combination of anæsthetics is often useful, it is to be employed with the greatest circumspection. It is obvious that without this the vigorous breathing of an ether anæsthesia may easily lead to too rapid assumption of chloroform unless this is supplied with great care in dilute vapour. The change from ether to chloroform is generally made on account of symptoms during the ether anæsthesia which it is desired to abolish. That is to say, there is generally no advantage in this particular succession of anæsthetics, and the combination is not settled upon beforehand, but is forced on the anæsthetist by the patient's behaviour during ether inhalation. Chloroform, we have seen, is often a convenient prelude to ether. The contrary rarely holds good. The most usual reasons for changing from ether to chloroform concern the respiration. Patients are occasionally met with who seem unable to settle down to smooth, regular breathing under ether. Either cough is never entirely abolished or expiratory straining persists or, although breathing is regular and smooth, moist sounds arise and show the undesirable presence of mucus in the air passages. Under these circumstances a change to chloroform may become essential. It is, however, right to point out that this change is often thought necessary by the inexperienced when they are deceived by the fact that they have never really got the patient quite free from the early spasm and cyanosis caused by ether. Freeing the airway and pushing the ether as well as giving frequent breaths of air will lead to anæsthesia with relaxed muscles and consequent rapid disappearance of blueness and spasm without any need for changing the anæsthetic. This applies frequently to cases in which the desire to change arises fairly early, within the first quarter of an hour or so of the administration. The genuine instances in which the change is really needed are usually seen later in the course of operation. The patient being then fully under ether, the change to chloroform must be made very carefully. Generally speaking the anæsthesia should be allowed to lighten until the coughing reflex is present. If the change is being made on account of mucus, the mouth should be opened and the pharynx sponged out. If there is no cough, the corneal reflex is to be looked for and chloroform not given unless it is distinctly present. Chloroform is then started gradually at first and the anæsthetist feels his way to the desired deep narcosis. The necessity for changing from ether to chloroform arises much less frequently during the proper use of open ether preceded by alkaloids than it did in the days when closed ether was frequently used for abdominal operations.

The Combination of Local with General Anæsthetics

In some branches of surgery it has long been customary to employ local anæsthetics in association with general anæsthesia. Thus the nose is often packed with wads soaked in cocaine solution prior to the administration of general anæsthetics for operations on the septum, and local anæsthetics are used within the urethra in conjunction with general anæsthesia. The object of this association has generally been both to secure complete absence of reflex susceptibility from the site of operation and to diminish the required amount of general anæsthetic. The use of local in conjunction with general anæsthetics has much increased, however, since Crile [1] showed reason to believe that this combination is necessary to achieve the best possible preservation of the patient from the effects of surgical trauma. This observer, basing his opinion on experimental and histological observation, stated that general anæsthetics, with the exception of nitrous oxide, do not protect the brain cells from the effects of stimuli reaching them as the result of peripheral damage caused by operation. " Ether anæsthesia offers no protection to the brain cells against the effects of trauma. The lipoid solvent anæsthetics probably break the arc which maintains consciousness beyond the brain cells somewhere in the efferent path." [2] Consequently Crile advanced the principle that stimuli must be prevented from reaching the brain by blocking the peripheral paths. This must be brought about by regional anæsthesia. His method of *anoci-association* aimed at complete protection of the brain from all noxious stimuli, whether from emotion, trauma, or toxic drugs. The psychic shock which may be caused by fright or other emotions is prevented by preliminary alkaloids and by the administration of nitrous oxide, traumatic effects are avoided by local anæsthetics, and toxic effects by withholding noxious drugs, including most general anæsthetics. Crile also insists on the importance of other measures, " feather edge technique," keeping raw tissues covered, etc., which, however, are within the surgeon's, not the anæsthetist's, domain. Whether or not Crile's theory, histological observations, and deductions are correct, there is no doubt that excellent results are obtained by thorough employment of the technique that he recommends. Subject to modifications, this consists in—

(1) Hypodermic injection of morphine gr. $\frac{1}{6}$, scopolamine gr. $\frac{1}{150}$, one hour before operation ;

[1] " Anoci-association," 1914.
[2] " A Physical Interpretation of Shock, Exhaustion and Restoration," Crile, 1921.

(2) Administration of nitrous oxide and oxygen ;

(3) Infiltration with 1 in 400 novocaine of all tissues within a wide area of the region on which the operation will encroach. The first injection is made into the skin itself ; the deeper structures are injected layer by layer, and no tissues are divided until they have been infiltrated.

(4) To prevent post-operative pain additional injections are made of solution of quinine and urea-hydrochloride ($\frac{1}{8}$ to $\frac{1}{2}$ per cent.).

Many workers have abandoned the use of the last-named solution, believing that it has led to destruction of tissue or to infection. Crile's method entails extra work on the part of the surgeon and renders the anæsthetist's labours correspondingly light. He is, in fact, merely occupied with keeping the patient unconscious. Any lack of necessary muscular relaxation or evidence of reflex sensibility is met, not by increasing the general anæsthetic, but by further local infiltration. In connection with the operation for *exophthalmic goitre*, Crile modifies the method into that which he describes as " stealing the thyroid." The subjects of this disorder being, as is well known, of a highly nervous and emotional nature, special precautions are taken to avoid the possibility of fright or any psychic shock. The patient is accustomed by several days' rehearsal to the application of the gas and oxygen apparatus and inhalation of the gases, and on the actual day of operation is unaware that anything further will be done to her than that to which she has become accustomed. When the technique is successfully carried out she awakes from operation unaware that it has been performed, and has been spared all the dread of anticipation. The condition of the patient after a long operation which has been performed with no general anæsthetic except nitrous oxide and oxygen, assisted by local infiltration, compares most favourably with that seen after the use of any other method of anæsthesia. It is, in fact, one of the chief recommendations of this combination that immediately after operation the patient can be given by the mouth any food or stimulant that is thought desirable. Particularly for elderly subjects who have been through a severe operation, this is, as Mummery points out, a matter of great importance and advantage. Even when the anæsthetist is unable to confine himself to " gas and oxygen " he reaps much aid from local infiltration. The amounts of open ether or C.E. mixture or chloroform which he must administer to ensure quiet are, of course, infinitely smaller than those necessary when the general anæsthetic is alone responsible for

preventing the effects of peripheral stimuli from manifesting themselves.

For operations on those parts of the body to which it is adapted the combination of **spinal analgesia with general anæsthetics** is often desirable. The very complete relaxation of the abdominal wall obtained by spinal analgesia successfully carried out is of the greatest service in many abdominal operations, among which that of prostatectomy may be especially mentioned. The subjects of this operation are often men of advanced years or men whose general condition renders deep narcosis with general anæsthetics especially hazardous. Yet in order that the surgeon may work with facility such a narcosis is generally necessary, unless the aid of spinal injection is obtained to produce the necessary relaxation. The objections to spinal analgesia when applied to nervous or frightened individuals, objections strongly supported by Crile's theory of psychic shock, may be met in one of two ways. Either so much use may be made of preliminary alkaloids that, when the time comes to make the lumbar puncture, the patient is drowsy and indifferent if not actually asleep, or else the puncture and injection may be made after the patient has been put into anæsthesia. When the latter course is pursued either the surgeon carries out the spinal injection, or if the anæsthetist does this he must temporarily hand over the charge of the general anæsthetic to an assistant. The technique and general management of spinal analgesia are described later (p. 379), and here attention need be drawn only to the effects of combining it with general anæsthesia. In the first place, whatever general anæsthetic is used is given with a sparing hand. Whenever possible gas and oxygen should be the chosen agent, but it must be admitted that there are very many subjects for whom it is not suitable in conjunction with spinal analgesia. Either there are respiratory defects in the patient which make it less adaptable than an open method, or else alterations in the position of the body demanded by the operator make the gas and oxygen apparatus inconvenient. Since, however, the general anæsthetic is needed in such comparatively small amounts, the inability to use gas and oxygen is not of very great moment. The small quantities of C.E. mixture or of chloroform inhaled to maintain unconsciousness during a good spinal anæsthesia rarely lead to any after-effects, and still more rarely to any undesirable symptoms during operation. The general anæsthetic is not given to a degree at which its effect on the blood pressure is material. Otherwise it might well be feared that the combination of the depression produced by the general anæsthetic with the lowering of blood pressure commonly associated with intrathecal injections would be highly dangerous.

Among the operations in the performance of which combined spinal and general or combined local and general anæsthetics are especially valuable may be mentioned Wertheim's operation for removal of the uterus and the abdomino-perineal excision of the rectum. In these and similar severe procedures the shock-preventing effects of the local or spinal analgesic are of immense benefit.

CHAPTER XIV

LESS COMMONLY USED ANÆSTHETICS

THE foregoing anæsthetics are, either individually or in mixtures or in succession to one another, the commonly employed agents for producing anæsthesia. Many other bodies have been tried at various times, and a few of the more important must be mentioned here. For a very complete list of anæsthetic agents, both past and present, the reader is referred to Gwathmey's book, " Anæsthesia " (1914).

Amylene was introduced by Snow in 1856, who found that he could produce with it insensibility to pain with an unconsciousness less profound than that of chloroform or ether anæsthesia. Hewitt remarks that in most of Snow's administrations of this body an analgesic rather than a truly anæsthetic condition appears to have been obtained. Amylene is extremely volatile, and consequently is quickly eliminated, patients recovering from its effects with rapidity. It could not be depended upon for the production of muscular relaxation. Under its influence the pulse and respiration are quickened, the colour heightened, the pupils only slightly enlarged, and perspiration sometimes evoked. Three to 4 drachms are needed to cause insensibility in the adult, and the vapour must be of a strength of about 15 per cent. with air. Some form of inhaler, semi-open or closed, is needed for the administration of amylene. It is not well suited to continuous inhalation, and therefore finds its proper application in the performance of quite short operations which do not need muscular relaxation. It causes less salivation than ether. After-effects are slight, nausea and vomiting being exceptional. The odour of amylene is unpleasant. Snow met with two fatalities in 238 administrations, and although it is doutbful whether these deaths should be attributed directly to the anæsthetic, their occurrence led to the disuse of amylene. The Academy of Medicine appointed a committee which investigated amylene soon after its introduction and reported upon it.[1]

Pental is the name given to a pure form of amylene.[2] It has been extensively used in dental surgery, but is less pleasant and

[1] *Med. Times and Gazette*, Vol. 1, 1857, p. 623.
[2] Hewitt's " Anæsthetics," 1912, p. 34.

more dangerous than either ethyl chloride or nitrous oxide. It was given with re-breathing from a closed inhaler, anæsthesia being produced in about forty seconds. Several fatalities with pental have been recorded.[1]

Amyl choride was found by Richardson to produce an anæsthesia too slow and profound for ordinary practice. It also greatly reduced the body temperature. About 1 ounce was needed for complete anæsthesia. The physiological properties of *butyl chloride* and its anæsthetic value are almost identical with those of amyl chloride.[2]

Bromoform (tri-bromo-methane; formyl tribromide) was proposed as a general anæsthetic by Nunneley in 1849. It is capable of producing rapid narcosis, but is too dangerous for ordinary use.

The anæsthetic properties of *carbon dioxide* have been alluded to in the physiological section of this book, and although in practice these properties are no doubt frequently made use of in closed methods of giving anæsthetics, yet carbon dioxide as an anæsthetic *per se* needs no further consideration.

Carbon tetrachloride produces an anæsthesia which is slow in arriving, but prolonged when present. Richardson stated that a vapour of 5 to 10 per cent. was necessary and that the quantity of tetrachloride to be used was from 4 to 8 drachms. The chief practical interest in carbon tetrachloride lies in the fact that hairdressers use it as a wash and that a fatality has been associated with this practice.[3]

Chloral is a narcotic which can produce complete surgical anæsthesia, and has been given intravenously for that purpose. Its use in this way has been found, however, too dangerous for adoption.

Ethyl bromide is very similar in its action to ethyl chloride. It is, however, more irritating to the respiratory passages, and it is less stable. Consequently a bottle or tube of ethyl bromide, once opened, should be used at once or thrown away, as it deteriorates quickly. Ethyl bromide has been extensively used for short operations. The Central Society of German Dentists record 14,921 administrations without fatality.[4] Three to ten c.c. constitute the anæsthetic dose, which should be given with restricted air supply. Anæsthesia is obtained in about half a minute, lasts about a minute and a half, and is quickly recovered from. Silk in over 130 cases found that the average time needed to produce anæsthesia was sixty-six seconds, and the duration of

[1] Hewitt's "Anæsthetics," 1912, p. 464.
[2] Gwathmey's "Anæsthesia," p. 718.
[3] *Lancet*, Aug. 7, 1909, p. 369.
[4] *Deuts. Monats. f. Zahnheilk.*, 1905, No. 11, 683.

anæsthesia forty-six seconds. Ethyl bromide is not to be confused with ethylene dibromide, which is a cardiac poison with slight anæsthetic action. It has been present as an impurity in some brands of ethyl bromide, and has been held responsible for untoward symptoms attending their inhalation. Excitement during the inhalation of a single dose of ethyl bromide is exceptional. Repeated applications of the inhaler, however, may be attended by vomiting, convulsions, and violent headaches. Consequently the anæsthetic is not to be used for any operations but those that can be performed with the anæsthesia of a single administration. For the details of a long operation under ethyl bromide the reader is referred to Hewitt's "Anæsthetics," p. 459.

Ethidene dichloride was introduced by Snow, who found its effects to be nearly the same as those of chloroform. A comparison of the two was made by the Glasgow Committee of the British Medical Association, who published the result of their investigation in 1880.[1] The average dose of ethidene dichloride per minute of anæsthesia was found to be 1·8 c.c., that of chloroform 1·7 c.c. The time taken to produce anæsthesia was 4·3 minutes for ethidene, 5·4 minutes for chloroform. Less excitement was observed than with chloroform, and the committee regarded ethidene dichloride as being both in point of safety and other respects half-way between chloroform and ether. Clover recorded 1,877 administrations of ethidene. He used his combined gas and ether inhaler, preceded the ethidene dichloride with nitrous oxide, and added the ethidene just as he did ether, giving it evidently with limited air supply. Tom Bird [2] described its administration from Junker's inhaler and J. H. Palmer [3] that from lint or a towel. Several fatalities have been reported in connection with ethidene dichloride.[4] The after-effects of its use are similar to, but less than, those of chloroform. Vomiting occurs with about equal frequency, but is of shorter duration after ethidene.

Hedonal is given to produce general anæsthesia by the method of intravenous infusion, as described in connection with ether (p. 135). The solution is made by dissolving hedonal in sterile saline at 75° F. The strength used is 0·75 per cent. The solution is filtered, boiled for five minutes, and stored in sterile flasks. It is given at not less than blood heat by continuous infusion, and the induction should not be too rapidly executed—100 c.c. infused every two minutes represent about the correct average

[1] *Brit. Med. Journal*, Dec. 18, 1880, p. 158.
[2] *Med. Times and Gazette*, Vol. 1, 1879, p. 62.
[3] *Lancet*, 1879, Vol. 2, p. 637.
[4] Hewitt, *loc. cit.*, p. 462.

rate, and on an average 500 c.c. are needed before anæsthesia is present. Then the rate of infusion is reduced to about 50 c.c. every two minutes. Too rapid infusion leads to cyanosis. It was thought that hedonal infusion would supply an excellent method of anæsthesia for operations upon the nose and throat. The long period of somnolence afterwards combined with prolonged insensitiveness of the larynx have, however, proved highly dangerous after this kind of operation. Deaths have occurred owing to the quiet inhalation of blood into the lungs under these circumstances, and hedonal should not be employed for any operation after which blood may enter the respiratory passages. Mennell,[1] who had a wide experience of hedonal at St. Thomas's Hospital, where the drug was introduced by C. M. Page, lays down three contra-indications to its use: (1) Any operation resulting in bleeding into larynx or trachea.[2] (2) High blood pressure, an enormous quantity of the drug being then needed to produce anæsthesia. (3) Patients in whom anæsthesia can be as safely and satisfactorily produced by other means. To these must be added pulmonary diseases and gross cardiac lesions. The best field for hedonal anæsthesia is cerebral surgery. Safety is secured by not allowing the skin reflex to be abolished. The corneal reflex is not to be relied upon under hedonal. The skin reflex persists even when muscular rigidity is abolished and a sufficient anæsthesia can be maintained if this reflex is not abolished, while safety is secured. Abolition of the corneal reflex implies danger.

Hydramyle[3] gave Richardson excellent results as an anæsthetic for quite short operations. It is described as sweet and pleasant to breathe, with very rapid action and equally speedy recovery. Why further experiences with this anæsthetic have not been sought does not appear plain.

Isopral has been used intravenously for the production of anæsthesia in the same manner as hedonal and ether. Burkhardt[4] recommends the combination of isopral with ether for intravenous use. Buxton[5] states that isopral, like hedonal, is less safe than ether for intravenous infusion.

Methyl oxide was investigated clinically by Hewitt.[6] He states that, "compared with the anæsthesia obtained by the recognised anæsthetics, that produced by methyl oxide was of a lighter type and was more liable to be followed by nausea and

[1] *Proc. Royal Soc. Med.* (Anæsthetic Section), Vol. 6, 1913.
[2] *Ibid.*, p. 1.
[3] Gwathmey, *loc. cit.*, p. 767.
[4] *Munch. Med. Woch.*, 1911, p. 778.
[5] Buxton's "Anæsthetics," 1920, p. 202.
[6] *Lancet*, Nov. 19, 1904, p. 1408.

distress." To some patients a mixture of 33·3 per cent. with 66·6 of air was given, to others 50 per cent. of methyl oxide and of air. The largely diluted mixture was not unpleasant to inhale, but gave an unsatisfactory anæsthesia.

Magnesium sulphate has been employed as an anæsthetic by intrathecal injection. Meltzer [1] experimented with this substance subcutaneously and by intravenous and intraspinal injection, and finally employed the last-named measure on human patients. He injected 1 c.c. of a 25 per cent. sterile solution of magnesium sulphate for each 12 kg. of body-weight, and found that after three to four hours it was possible to operate painlessly on the legs and pelvic regions. The treatment of tetanus by intravenous infusion of magnesium sulphate solution showed that the substance might safely be introduced into the general circulation in this way, and Meltzer believes that he caused anæsthesia by such injection, not merely motor paralysis. The injections were followed by intense thirst, and the patient remained for nine minutes without spontaneous respiration. This was after a 10 per cent. solution had been used, the others being 6 per cent.[2] Much further experience is required before we are warranted in regarding magnesium sulphate as a trustworthy general anæsthetic. Recently Gwathmey has employed subcutaneous injections of 300 c.c. of a 4 per cent. solution as a preliminary in combination with morphia.

Nitrogen can be used to produce a brief anæsthesia, which it brings about purely by oxygen deprivation. The gas can therefore be scarcely regarded truly as an anæsthetic, having no positive anæsthetic qualities. The clinical experiments carried out by Hewitt and George Johnson [3] supplemented with greater accuracy the information obtained earlier by Burdon Sanderson. Hewitt obtained anæsthesia with nitrogen combined with as much as 7½ per cent. oxygen. He used also ·5, 3, 5, and 6·6 per cent. Anæsthesia was always rapidly produced and was accompanied by jerky, irregular breathing and cyanosis. It lasted less time than with nitrous oxide given for the same length of inhalation. Johnson, reporting on the administrations of nitrogen with ·5 per cent. oxygen, stated that the maximum time needed to produce anæsthesia was 70 seconds, the minimum 50 seconds, and the average 58·3 seconds.

Hypnotism can be used for the production of surgical anæsthesia. Only some subjects are amenable, however, to deep hypnosis, and even for them several applications of the treatment

[1] *Berlin Klin. Woch.*, 1906, No. 3, p. 73.

[2] Peck and Meltzer in *Jour. Amer. Med. Assoc.*, Vol. 63, p. 1131, No. 6.

[3] Hewitt, *loc. cit.*, p. 466.

may be needed before success is achieved. It is obvious, therefore, that hypnotism is not to be chosen as the means of anæsthesia unless there are special reasons making it preferable to all other available methods. This is the more true because the hypnotic state itself, especially if repeated, is not entirely innocent of injurious mental effect. "A sort of hypnotic habit has been developed in some people, manifesting itself during convalescence so that almost any unusual incident would recall the hypnotic state" (J. Walsh). It is true that suggestion plays a large part in the successful induction of ordinary anæsthesia and to a certain extent accounts for the greater success of the experienced anæsthetist. The confidence which he evidences in the oncoming of unconsciousness is conveyed to the patient and predisposes him to that state. Proof of the power lying in the anæsthetist's suggestion is afforded by the well-authenticated instance when, finding himself short of nitrous oxide for what should have been a "gas" administration, the administrator, proceeding as though he were really giving the anæsthetic, obtained anæsthesia enough for the extraction of a tooth without actually administering any drug at all. Anoxæmia no doubt helped him, but the main effect was probably due to suggestion. There is, in fact, every advantage to be gained by using suggestion to aid the induction of anæsthesia; but this is, of course, entirely a different thing from attempting to use the true hypnotic states as the means of insensibility.

Hypo-narcosis,[1] advocated by Friedländer, puts hypnotism to use in a novel way. It becomes a preliminary to and sequel of anæsthesia. The narcotic state is made to supervene upon the hypnotic, the latter being used just before anæsthetic administration. Directly narcosis ceases after operation, hypnosis is again used. It is stated that the amount of anæsthetic required is reduced by one-third or two-fifths. Hypnotic after-treatment is employed to secure rest and sleep. Only a certain proportion of persons are susceptible to the deep, hypnotic sleep which is necessary for a surgical operation. Furthermore, the state, when induced, is not completely under control, so that during a long operation it might cease too early to be effective. Infants can rarely be hypnotised. Children over six years or so are usually susceptible. Yet only a proportion of these, as of adults, can be made insensitive to surgery. The most usual method of securing hypnosis consists in getting the patient to fix his gaze steadily on an object placed a little below the level of his eyes. The operator's own eyes may well be used. The patient is first talked to and told to try and keep his mind vacant, not to analyse

[1] *Deutsch. Revue*, March, 1921.

his sensations and to expect that he will get drowsy and his eyelids heavy. He is seated comfortably or lying down and the room is but poorly lit. After a little suggestions are made to him that his eyes feel heavy, that he is getting drowsy, that his limbs are becoming heavy. If these suggestions are not soon realised, in fact, the patient is told to close his eyes and suggestions are repeated. The process of inducing hypnotic sleep may take half an hour.

The reader wishing for further information about hypnosis and anæsthesia should consult Bramwell's book "Hypnotism: its History, Practice and Theory" (London, 1906) and Tuke's "Treatment by Hypnotism and Suggestion" (London, 1907).

Acetone, ethyl nitrate, benzene and turpentine, when vaporized, have all been found capable of producing anæsthesia, but as practical anæsthetics do not merit consideration.

Finally, the **electric current** must be mentioned as an anæsthetic. We have seen that the most recent researches into the nature of anæsthesia show that this state is accompanied by an alteration in the electric conductivity of cell membranes, and it will not be surprising if the future brings electricity as a means of procuring anæsthesia into greater prominence than it has yet reached. Professor Leduc[1] produced both analgesia and true anæsthesia in animals. Experimenting on himself he stopped short of producing anæsthesia, but his pupil Robinovitch on January 24, 1910, anæsthetized a patient for amputation of toes, this being, according to the account, the first occasion on which a human being was electrically rendered anæsthetic for a surgical operation. The anæsthesia lasted forty-five minutes. Evidently, however, the condition was analgesia, not anæsthesia, for consciousness was retained throughout, the patient talking and stating that he was absolutely without pain. Recovery was complete and without incident. *Electric sleep,* however, has been produced, but as yet I can find no account of a patient having been operated on while both unconscious and insensitive from electricity. The current employed is a rapidly interrupted direct one, and the apparatus and technique require an expert electrician. The greatest care, in fact, is necessary both as to the source and the conduction of the current. For the patient mentioned above the current was drawn from the storage batteries of an automobile and passed through a rheostat, two meters, and an alternating switch. One electrode was placed over the sacral vertebræ and others over the main nerves of the leg. The current was interrupted 6,000 to 7,000 times per minute, the period of passage of the current being one-tenth of the entire time. The meters

[1] "Le Sommeil Electrique," Masson & Co., Paris.

registered 54 volts and 4 milliampères of current through the body locally. To produce sleep one electrode is placed on the head, the other in the palm of the hand. The current is started slowly and gradually increased. The measure seems of great value for insomnia. Forecasting the possibilities of electric analgesia and anæsthesia, Butcher says : " Inhibition is produced by an electrical stimulation of the nerve cells with a rhythm which is incompatible with their physiological activity. We have reason for supposing that each muscle and nerve is attuned to its own special period of electric stimulation, and therefore of electric inhibition, so that in the near future we may be able to put to sleep a tired member or an injured organ without altering the general consciousness " (*Lancet*, November 16, 1907).

CHAPTER XV

THE CHOICE OF ANÆSTHETIC

A. According to the Site and Nature of the Operation

From preceding pages it will have been gathered that, so far as routine is possible in the use of anæsthetics, we recommend for routine use nitrous oxide with air or oxygen whenever possible, ether as next choice, mixtures next, and chloroform last of all. And it will have been also realized that many departures have to be made from routine practice owing to special circumstances and for special conditions and operations. Although very many operations can be satisfactorily met on these routine lines, there are also many where the choice of anæsthetic requires special consideration on account of the nature of the operation as distinct from that of the patient. Some anæsthetics are particularly well adapted to some operations and but ill suited to others. The degree of narcosis necessary also varies greatly according to the part of the body that is being operated upon, as well as according to the operation, even the steps of the operation, being performed. Thus, for example, it would be the worst practice to use chloroform for dental extraction, or nitrous oxide alone for operating on internal hæmorrhoids. The first would expose the patient to a risk quite unnecessary for the trifling operation performed, and the second would provide the least potent anæsthetic in order to overcome one of the most sensitive reflexes of the body. The patient in the latter case would be inconveniently mobile, in the former he might be rendered permanently motionless. Yet this is no fanciful illustration, for the records of deaths under anæsthetics show several examples where the fatality has taken place under chloroform given for extraction of teeth, when there was no good reason why this rather than a less dangerous drug should have been selected.

Superficial operations upon the head and face—removal of sebaceous cysts from the scalp, small growths or abscess on the face, for example—are usually well performed under gas and oxygen. When the incision has to be made on a part of the face covered by the face-piece, then, unless there is room for the

nose-piece without inconvenience to the operator, gas and oxygen cannot be used if more than about a minute's analgesia is needed. When a few minutes' anæsthesia is needed gas and ether is usually convenient, the patient being charged up, so to speak, with ether for several minutes and the anæsthetic then completely withdrawn. For longer operations that do not permit the face-piece of a gas and oxygen apparatus the administration will have to be continued by means of a tube inserted into the mouth conveying ether vapour from a Shipway's apparatus. Induction will best be secured by C.E. mixture, as open ether causes very free oozing, and also the necessary pad on the face will probably interfere with the site of the operation. Chloroform may have to be used for maintaining the narcosis in robust subjects.

Prolonged *plastic operations upon the face and jaw*, most uncommon in ordinary life, were frequently required for the injuries of war. They threw much strain upon the anæsthetist as well as the surgeon, and various methods were tried in order to find the process best adapted to give an equable, safe narcosis with a minimum of inconvenience to the operator. It may be safely said that intra-tracheal insufflation of ether proved itself to be the most widely applicable and safest method. Many patients had to be operated on a large number of times, and this in itself precluded the use of methods involving preliminary laryngotomy or tracheotomy, which otherwise were well adapted to the operations. Two objections alone seriously opposed the intra-tracheal method. The first was the great difficulty in some patients of passing the tube owing to great scarring and fixation of tissues of the throat and the tongue. This difficulty has to be overcome in most instances, as Shipway [1] points out, by flexing the head instead of attempting to pass the tube in the usual extended position. The other objection sometimes raised by operators was that the intra-tracheal tube was in their way during operation. Some administrators adopted the sitting position and administration of chloroform through Kühn's tube for these operations. This instrument, however, is more of an obstacle for the operator than the intra-tracheal tube. Where intra-tracheal insufflation is for any reason not applicable and an opening into the larynx or trachea not desired, then these operations are best managed with the aid of rectal anæsthesia supplemented, as necessary, by inhalation of ether vapour through nose or mouth. The noticeable freedom from sickness after these operations performed under intra-tracheal insufflation has been attributed to the absence of all swallowing owing to the packing of the pharynx and the presence of the tube. Thus no

[1] *Proc. Royal Soc. Med.*, Vol. 13, No. 6, p. 22.

ether-laden saliva or mucus enters the stomach to be returned on recovery from narcosis.[1] Some surgeons preferred local anæsthetics to any form of general anæsthesia for plastic operations upon the face, operating on small areas on many separate occasions.

Operations *upon the skull* are generally either for fracture or decompression for the remedy of lesions within the brain. The patients often are in a state requiring little anæsthetic, and at any rate after the scalp incision narcosis should be of a light degree. Chloroform with oxygen is generally the best anæsthetic to employ. Ether and oxygen may be chosen when the vitality of the patient is already low. Much shock may accompany removal of large portions of the skull, and to counter this it may be necessary to replace the chloroform by open ether, or by ether and oxygen. The surgeon's arrangements frequently make the use of a drop-bottle highly inconvenient, if not impossible, for head operations. Either a Vernon Harcourt with long tube, or some form of pumping apparatus separated from its face-mask by a long tube, is necessary. The face is generally covered from view by the surgeon's towels, and the anæsthetist has to rely entirely on the breathing and the radial pulse for knowledge of the patient's condition. If absolutely necessary, he must refer to the eye now and then, taking care to get at it from below the towels and not to upset the surgical cleanliness of all exposed surfaces. For operations on the occiput a head-rest beyond the table is necessary; otherwise the face is pressed on to the table, breathing obstructed and the anæsthetist's work made almost impossible. Often for keeping unobstructed respiration he will have to prop the chin up by a hand kept under the towels throughout, and a small prop between the patient's teeth may be necessary in order to act as a fulcrum against which to exert the necessary pull upon the lower jaw. During all intra-cranial operations it must be remembered that increase of anæsthesia attends the opening of the dura. Mennell[2] points out that this probably arises from the sudden increased supply of blood to the brain owing to the relief of tension. Extreme shock with great fall of blood pressure is often present owing to operative interference with the bulbar centres. For these reasons chloroform is to be avoided in all extensive intra-cranial operations. Intra-tracheal ether is the method of choice and is essential when extreme flexure of the neck is demanded for operations on the occiput. It should also be always chosen for operations on the pituitary body.

During the *mastoid operation*, the face is generally accessible

[1] *Presse Medicale*, Aug. 29, 1918, p. 441.
[2] *Proc. Royal Soc. Med.* (Anæsthetic Section), March, 1922.

and a drop-bottle may be used if desired; moreover, shock is not generally severe with this operation. Induction for it may quite well be carried out with open ether or C.E. mixture in most cases, and these may be continued throughout, or a weak, constant chloroform vapour may be used for maintenance. Very little anæsthetic suffices during all the time that bone is being chiselled or gouged. I have used gas and oxygen for the operation, which took an hour, on a girl already very ill with septic absorption. During mastoid operations the surgeon is often inconvenienced by the constant oozing of blood, which obscures his view of the minute anatomy of the bone with which he is dealing. The usual method of dealing with this bleeding is by frequent mopping with small strips of gauze. The instrument devised by S. Jankauer very efficiently removes the blood, and can be used at the same time to deliver the anæsthetic vapour. This double pump has proved of service in many operations about the head, mouth and throat, where effused blood has to be quickly removed. When the sucker is in the pharynx care has to be taken that it does not draw towards itself the uvula or small portions of the soft palate, so powerful is the sucking action that the instrument can exert if the cylinders are allowed to revolve too rapidly.

The apparatus can be obtained in this country from Messrs. Mayer and Phelps, of London.

For operations upon the *brain* the indications are those given for skull operations. Little or no anæsthetic is needed during the manipulation of the brain matter itself. It was formerly the common practice to use morphia hypodermically before giving chloroform for cerebral operations. In most instances the morphia should be avoided because of its depressing effect upon the respiratory centre. In patients with cerebral trouble this is already often injuriously affected by the abnormal intra-cranial pressure, and anything likely to increase still further the respiratory difficulty is to be avoided. Partly for this reason, and partly for keeping hæmorrhage as slight as possible, chloroform, which will not cause any turgescence of the brain, used to be preferred to ether for maintaining narcosis during these operations. Nowadays surgeons prefer to rely on efficient hæmostasis and the use of ether with or without oxygen.

Operations involving *the mouth*, for removal of *part or whole of the tongue, growths on palate or fauces or lower or upper jaw*, require special arrangements for preventing the entrance of blood to the air passages. Either it must be made mechanically impossible for blood to reach the larynx, or else the anæsthesia must be

of such a light degree that, if blood enters the glottis, it will be coughed out. The former plan is usually the best. To secure this freedom from blood inhalation, several measures are available :

(1) Intra-tracheal insufflation of ether.

(2) Preliminary laryngotomy or tracheotomy, the anæsthetic being delivered through a tube inserted into the larynx or trachea, the parts above being shut off by gauze packing, sponge, or by using a Hahn's tube.

(3) Ether through Crile's tubes inserted into the nose, the pharynx being carefully packed off with gauze.

(4) The adoption of a completely lateral position of the patient, so that any blood entering the cavity of the mouth falls into the lower cheek, from which it can be easily removed.

(5) A sponge firmly packed into the post-nasal space and lateral position of the head suffice in lesser procedures, as, for example, the ordinary operations upon the antrum.

(6) Rectal ether, the entrance of blood being prevented by sponging and the lateral position.

(7) Administration through Kühn's tube.

(8) Operating with the patient in the Trendelenburg position.

Whether rectal ether is solely relied upon or not it is of the greatest service in operations for removal of *the tongue* in plethoric individuals. The kind of man on whom a tongue operation has to be performed is often just the most difficult for anæsthetics, and if it is proposed to maintain the anæsthesia by inhalation this may be found hard to achieve through the mouth or nose unless the patient is already subdued by rectal ether. When the anæsthetic is given through a laryngotomy or tracheotomy tube, then it is generally quite easy to maintain a sufficient narcosis. In all tongue operations a deep degree of narcosis should be obtained before the operation is allowed to begin. Only in this way does the anæsthetist keep full control of the patient, which he may find very difficult to obtain if the operation starts with the patient lightly under, and narcosis has to be deepened by the diluted vapour pumped through a tube and impeded by blood and the surgeon's sponges and manipulations. In former days chloroform had to be relied upon for the maintenance of anæsthesia, whether or not ether was used in induction. Now, however, by using Shipway's warm vapour apparatus ether can be safely and efficiently employed whether it is delivered into the cavity of the mouth or directly into a tube in the larynx or trachea. In the latter circumstances the orifice of the efferent

indiarubber tube of the apparatus should rest just inside the tube in the patient's air-way, so that warmth of vapour may not be lost in passing through an additional metal tube. The objection has been raised against intra-tracheal insufflation in operations for cancer of the tongue that portions of the growth may be removed by the tube and implanted lower down. There seems to be no evidence that such an accident has actually occurred. In the presence of a large growth of the tongue, however, or of any growth in such a position that it would be damaged by the passage of the tube, probably the intra-tracheal method should be abandoned in favour of a preliminary puncture laryngotomy. In all operations of the group here referred to it is advisable that breathing should go on through the mouth rather than the nose, unless, of course, it is being conducted through a tracheal tube. When, therefore, the patient tends to breathe partly or wholly through the nose, after anæsthesia has been obtained and the gag placed in position, the anterior nares should be plugged with gauze to ensure oral respiration.

Dental operations are mostly performed under nitrous oxide, and are therefore described in detail in the chapter devoted to that anæsthetic (pp. 161, *et seq.*).

In operations upon the *antrum* care must be taken not to open the mouth too widely, as this stretches the cheek and inconveniences the operator. When the patient is placed with the affected side of the face downward a Mason's gag can be used on the other side of the mouth, and, blood escaping freely into the dependent cheek, very little sponging is needed. When the operator prefers to have the affected side uppermost or the head in the middle line, then a sponge with tape attached is packed into the posterior nares and a Doyen's gag used on the sound side.

The operation for *cleft palate* is usually performed on young and often ill-nourished infants. A narcosis is required deep enough to avoid all gagging and contraction of the fauces during the surgeon's dissection and passing of sutures. Ether by inhalation is not well suited to these young infants. Yet prolonged deep chloroform narcosis involves them in considerable risk. Generally this plan works very well—to induce anæsthesia by C.E. mixture, obtaining a deep narcosis and dropping pure ether on the mask for the last two minutes of induction. The infant is then placed in the appropriate position, viz., with a pillow behind the shoulders, the head resting on the occiput and the larynx at a higher level than the mouth. The mouth is now opened widely with a Lane's gag (Fig. 37) and anæsthesia is maintained by blowing in warm ether vapour from a Shipway's apparatus. To this chloroform can be added, or if necessary ether can be replaced

by chloroform. Such necessity arises only from excessive mucus or congestion and is rarely met. An alternative method is to use rectal ether. When this is retained it provides an excellent and safe narcosis for children. It is not easy, however, to ensure in infants the retention of enough of the injection. Generally enough will be retained to supply, at any rate, a partial narcosis, and this diminishes considerably the amount needed by inhalation. An important practical point is to ensure deep narcosis before producing the over-extended position of the neck. If this is adopted while the infant is still incompletely anæsthetized there will be holding of the breath and delay in getting full narcosis, even if it does not become necessary for this purpose to replace the infant in the normal dorsal position. With the head in the position described blood gives no trouble during the operation. It does not tend to enter the air passages and can be accommodated to a considerable extent in the back of the pharynx, even if the surgeon does not frequently remove it. When it has collected in some quantity the head can be turned completely to one side, allowing the blood to fall out of the dependent cheek. Some surgeons prefer to repeat this manœuvre occasionally rather than sponge away the blood. Although these infants should be deeply narcotized till all the needed sutures are tied, very little anæsthetic is needed to keep up the required condition provided that proper anæsthesia has been present from the beginning of operation. When the operation is performed under chloroform throughout, the infants are often of an alarming pallor and feebleness by the end, in marked contrast to their usual state under the treatment described above. In older children or adults, who rarely, of course, need this operation, chloroform is more often required, at least for maintenance of anæsthesia.

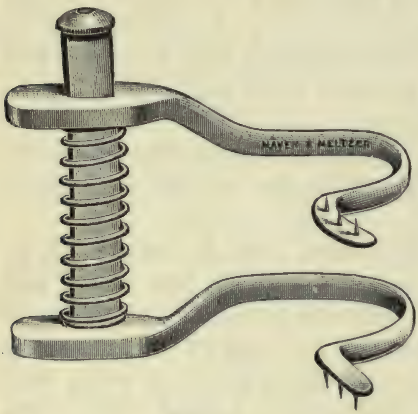


FIG. 37.

Intra-nasal operations upon ethmoid and frontal sinuses, for removal of turbinated bones, and similar procedures involving the presence of blood in the nasal passages, require either a post-nasal sponge, lateral position, or intra-tracheal insufflation. The latter is rarely necessary for these comparatively slight operations. Generally they are perfectly well carried out with complete

convenience to the surgeon in this way. Firstly, a degree of narcosis is induced in which the corneal reflex is just absent. This is done by a little C.E. mixture supplemented by open ether. The mouth is opened by a Mason's gag and the surgeon inserts his post-nasal sponge, which has a tape firmly attached to it. Pressing in this sponge affords a very complete test of the narcosis. There will be gagging and attempted retching if the anæsthesia is in the least degree too light These symptoms being absent, the head is placed to suit the surgeon, preferably well on one side, and a Hewitt's air-way is put into the mouth. Then while the operation proceeds any further anæsthetic needed is pumped into the air-way from a Shipway's apparatus. Some surgeons prefer to perform these operations with the patient sitting up and no post-nasal sponge. Frequent sponging out of the pharynx is then needed, and the narcosis cannot be kept safely so deep that the coughing reflex is absent. The sitting position is used in two different forms. In one the patient is in a chair with his feet on the ground. In the other his lower limbs are horizontal on the table, merely the upper part of his body and head and neck being in the sitting position. The former has the drawback that the patient always tends to slip down in the chair, and it is not easy to keep his head in the required place. In fact, for comfortable work with this position an extra nurse is required whose duty is solely to keep the head as directed and to steady the gag, the anæsthetist's hands being fully occupied with the pump of his apparatus and keeping the tube conveying the vapour in the proper position at the side of the mouth. If he uses a foot-pump he can spare a hand for the gag. The use of a chair also occasions considerable inconvenience when the operation is finished and the patient is to be lifted back to bed. Lifting a perfectly flaccid, bulky individual from a deep-seated chair into which he is sunk and which gives no facility for getting beneath the occupant is no mean feat of skill and strength.

Submucous resection of the nasal septum is conveniently managed in exactly the same way as the above, but a post-nasal sponge is not needed if the surgeon uses adrenalin injection before anæsthesia. Many surgeons apply cocaine or novocaine to the nasal mucous membrane beforehand, and also inject adrenalin. These measures help the anæsthetist enormously, and a very light degree of narcosis can be kept up with perfect immobility of the patient. It is important to remember that adrenalin injections must be made before the anæsthetic is begun. Adrenalin injected into a person lightly under chloroform is fraught with danger.[1] For maintaining the bloodless field, which is so essential

[1] *Proc. Royal Soc. Med.*, Vol. 13, No. 6, p. 4.

to the surgeon's convenience in these operations, all congestion must be avoided. This can only be if free oral breathing continues throughout, and it is to ensure this that the air-way is inserted. If that is not done there will often be a tendency on the part of the patient to attempt breathing through the nose, which at once interferes with the operator's view. If no air-way is used, it is generally necessary to keep the tongue forward by means of a tongue-clip, in the loop of which is hung some heavy instrument, such as a Mason's gag. Otherwise a small prop must be kept between the teeth in order that the lower jaw may be levered well forward throughout and so keep the tongue from obstructing the larynx, which in many subjects it will do, being drawn back with each inspiration. Anæsthesia having been induced by an open mask and drop-bottle is most conveniently maintained by the use of Shipway's warm vapour apparatus. In easy subjects ether vapour throughout suffices. In others chloroform may be added to a greater or less extent, and in some chloroform alone is used. Keeping an even but light narcosis, the anæsthetist uses chloroform for these patients with a minimum of risk, even when the sitting position is employed. The operation involves little shock and less hæmorrhage, the preliminary drugs are largely responsible for analgesia, and the induction stage has been passed. A sheet of sterilized linen or similar material covers the patient's face, having an opening cut in it large enough to expose the nose and upper lip. The anæsthetist keeps his delivery tube under this covering and is thus entirely free from interfering with the surgeon's cleanliness or movements. When a sheet of this kind is not employed, its objects may be met by fastening a broad piece of sterile gauze across the face from ear to ear below the nose. In this a hole must be cut to admit the anæsthetist's delivery tube.

Operations upon *the spine* for fracture or for removal of spinal tumours offer difficulty to the anæsthetist owing to the prone position of the patient. When extensive they are also apt to be attended by severe shock. Whenever the intra-tracheal insufflation of ether can be employed it entirely overcomes any inconvenience due to position. This method of anæsthesia for operations for spinal tumour is approved by Percy Sargent. It is especially of advantage, in Mennell's opinion, for high spinal operations. Whether used intra-tracheally or not ether is to be chosen for these operations. Clover's inhaler with the bag removed is often convenient.

Removal of Tonsils and Adenoids.—The most appropriate anæsthetic for these operations depends largely on the method which the operator adopts. There are, broadly speaking, two

different kinds of operation to be considered—(1) a quite short removal of one tonsil or of adenoids only, or of two easily removed tonsils; (2) removal of tonsils and adenoids, or of one or both tonsils when these are adherent.

In the first class of case a single full administration of "gas and oxygen" or of ethyl chloride will often give ample time for complete removal. Gas and oxygen is not suitable if the patient is a child under ten years or so. For this brief anæsthesia to be sufficient, however, it is essential that anæsthetist and operator should be thoroughly conversant with one another's practice. There is not a second to spare, and unless the two work together so smoothly that no moment is lost the result will not be satisfactory. It should be a primary principle in all operating that the anæsthetic should not handicap the operator by making him work against time. The principle holds with these short throat operations as with others, and unless the minute or so provided by gas and oxygen or ethyl chloride amply suffices the surgeon for the complete removal, and also allows him to satisfy himself afterwards that hæmorrhage is not taking place and that he leaves the pharynx just as he desires, then a short anæsthesia should not be attempted. For conditions such as are present in out-patient clinics, where many patients must be operated on in a limited time and must be fit to return to their homes after a few hours, these short administrations are inevitable. They are not the method of choice, but of choice under the circumstances. That tonsils and adenoids can be satisfactorily removed under ethyl chloride is plentifully proved by the work of many institutions, and I may merely quote our experience at St. George's Hospital. During the last fifteen years Mr. Barwell and Mr. Colledge have operated on over 6,000 cases. We have had no death, and have had but two cases where the patient's condition after or during operation caused any anxiety. The anæsthetics have almost all been given by Dr. Ll. Powell or myself. Ethyl chloride in amounts from 2 to 5 c.c., according to size and age of patient, have been given from a closed bag after the manner described (p. 221).

Gas and oxygen or gas and air has been used only in the older subjects, adults or children over twelve; and these have been a small proportion of the whole number.

Prolonged use of nitrous oxide and oxygen does not give a narcosis deep enough for dissection operations. For these and for enucleations by guillotine, which are not easy enough to be performed under the short anæsthesia described above, **a deep ether anæsthesia is required**. This is to be obtained by the free use of open ether, which may, however, be preceded by C.E.

mixture for induction. Some authorities are adverse to the use of anything whatever except ether. My own preference is for inducing the early stage of narcosis with C.E. mixture. Afterwards ether is given to the degree when the pupils are enlarged and the cords abducted.[1] If the operation takes so long that narcosis is becoming light enough for gagging or attempts at coughing that might impede the operator, then warm ether vapour is introduced into the mouth by a metal tube and Shipway's apparatus. By this means the patient can be kept deeply anæsthetized for an indefinite time while the surgeon is busy with the tonsils. When he has finished with these and with any steps that he desires to take for stopping bleeding, the anæsthetic is withdrawn and the adenoids, if necessary, operated upon. It is wise to allow the narcosis to rise again to a level of only light anæsthesia after the tonsils are out, and while the surgeon is looking for and controlling the bleeding. This ensures against secondary hæmorrhage, which might otherwise follow from vessels which showed no loss of blood during the lowered pressure of deep narcosis. In order to reach with ether the deep narcosis necessary for the quiet performance of these operations Rood [2] has pointed out that some reinforcement is necessary of the method usually adopted for giving open ether, and by the use of thick towels over the mask what is almost a semi-closed process is carried out. The result obtained, however, is different from that which accompanies very deep ether narcosis with closed methods, for there is no cyanosis, the patient remaining rosy pink in the face, and there is no exaggerated breathing. On the contrary, the respiration is rather shallow when the full degree of narcosis is attained. Most surgeons who dissect out the tonsils require an anæsthesia so deep that the fauces are immobile. Some prefer that this should be maintained with chloroform owing to the less hæmorrhage at the time. The anæsthetist should always give his opinion in favour of ether, because there is no question of its much greater safety for this very deep anæsthesia. Hæmorrhage, too, if more obvious at the time, is really less to be feared than when chloroform is used, for then it is more likely afterwards [3] (Tilley). When tonsils can be removed by the guillotine without dissection a less degree of narcosis than that described above is sufficient. The ordinary degree of full anæsthesia, such as is reached, for instance, before the abdomen is opened, generally suffices for the quiet removal with the guillotine of both tonsils; it can then be reinforced by a short reapplication of the mask

[1] *Proc. Royal Soc. Med.*, Vol. 13, No. 6, p. 22.
[2] *Ibid.*, p. 4.
[3] *Ibid.*, p. 11.

before the adenoids are dealt with. **The position in which the patient is placed during these operations is of first importance,** and is regulated by the principles already laid down. When the tonsils can be removed by guillotine, *i.e.,* without long dissection, the following plan is perfectly satisfactory. The patient lies flat on the back and the pillow is withdrawn from behind the head when full anæsthesia is present. The mouth being opened by Doyen's gag on the left side, the tonsils are removed one after the other, the head remaining straight. Then a nurse or assistant, standing on the patient's left side, rapidly turns the patient so that he lies on his right side, his left thigh being well twisted over the other. The operator now removes the adenoids, and in the lateral position now maintained he can be as deliberate as he pleases in inspecting the results of his operation and looking for bleeding. No blood can enter the larynx. Cold water is sponged over the patient's face and his side attitude kept up until he has coughed or retched or shown obvious signs of returned consciousness. The position most favoured for the dissection of tonsils during deep anæsthesia is that in which the patient lies on his back, his shoulders raised by a sandbag and his head resting on the occiput. The larynx is thus placed well above the pharynx, where blood may accumulate and be easily removed without fear of inhalation. This position should not be instituted till full anæsthesia has been obtained. During the induction the patient must lie comfortably with his head slightly raised and turned to one side, as for other operations. The combined gag and tongue depressor known as Davies' gives a very fine exposure of the pharynx (Fig. 38). It serves to keep the tongue forward as well as down. The instrument also carries an attachment through which the anæsthetic vapour can be introduced from a Junker, Shipway, or similar apparatus. This gag is made in various sizes, and is a useful adjunct for tonsil operations. It cannot be conveniently inserted till the patient is fully under. For small children and infants the gag shown in Fig. 39 (O'Dwyer's)

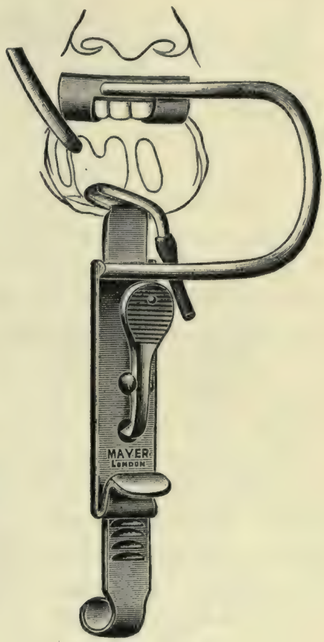


FIG. 38.

is a very suitable instrument. Placed well back on one side of the mouth the flanges do not slip, even off a toothless gum, and the gag is not in the operator's way, whichever side he is working. Doyen's gag is shown in Fig. 40.

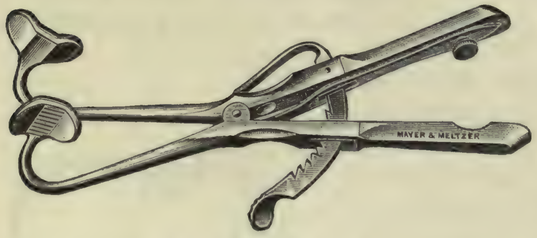


FIG. 39.

Prolonged dissections for removal of *glands of the neck* should be treated on the same lines as those laid down for thyroid operations. These procedures often involve considerable loss of blood as well as much operation shock, and they take place commonly on young subjects. The use of ether and very careful attention to preserving the body heat are our best safeguards. The necessary steps for keeping a free oral respiration without interfering with the surgeon must be carried out in the way described in connection with mastoid operations. Wounding a large vein and the entry of air into it have caused collapse during a neck operation. The immediate treatment required is hypodermic injection of strychnine. Closed apparatus of all kinds is best avoided for operations on the neck. It is too apt to cause congestion and increase bleeding. Induction by C.E. mixture followed by warm ether vapour is the best routine method. This should always be preceded by an atropine injection. Longhurst's tongue depressor is often the most suitable means for keeping the air-way clear and delivering the anæsthetic vapour.

FIG. 40.

Operations upon the *thyroid gland* may be short, easy, and devoid of all special risk, or they may be among the most trying of surgical procedures. This depends on whether or not the tumour involves the trachea or is associated with the tachycardia and nerve symptoms of exophthalmic goitre. In the simple cases where there are no involvement of the air passages and no

constitutional symptoms open ether or gas and ether answer perfectly well. When there is hoarseness, dyspnœa, or obvious displacement or flattening of the trachea, it is very likely that the respiratory difficulty will increase during the inhalation of any anæsthetic. Some authorities believe that this probability is enhanced by the use of ether, and therefore prefer chloroform for these patients. Experience points, however, to the greater safety of ether even in the circumstance mentioned, provided that it is preceded by atropine, is given by an open method and is not pushed to an extreme degree. Induction may very well be begun by C.E. mixture, which is continued only till loss of consciousness. Mr. James Berry [1] has pointed out that before any operation upon the thyroid the anæsthetist should not begin until the surgeon is ready to operate at a moment's notice. The necessity may arise unexpectedly owing to obstruction to breathing being caused by the swelling of an undetected extension of the growth. This happened to a woman in my own practice. There was no dyspnœa beforehand and no evidence of tumour behind the sternum. During the induction of anæsthesia extreme dyspnœa began with retraction of ribs and every symptom of obstructed inspiration. No manipulation of jaw or tongue was of any service. Tracheotomy was impossible from the position of the goitre, but directly the surgeon, who was hurriedly fetched to the anæsthetic room, passed his finger behind the sternum and shelled out the lowest part of the tumour respiration was relieved and the rest of the operation was performed at leisure. The narcosis should be kept light after the skin incision, and even for this a stage should be reached only just deep enough to abolish the corneal reflex. The position of the head where dyspnœa is present is of great moment. Before beginning the administration the anæsthetist should find out to what extent the neck may be extended without seriously hampering the breathing. This amount of extension must not be exceeded during operation. While this is in progress the head must be kept perfectly still in the correct position, and an extra pair of hands, of nurse or assistant, will generally be needed for this purpose. Rectal ether I have often found very well suited to operations for the removal of simple goitre. Mr. Dunhill,[2] whose experience in the matter is very great, speaks of having abandoned that method after two fatalities. This surgeon recommends open ether for thyrotoxic cases and tracheal insufflation when there is tracheal obstruction. Intra-tracheal insufflation of ether is warmly recommended by some authorities. There are, however, two

[1] *Proc. Royal Soc. Med.*, Vol. 13, No. 8, p. 11.
[2] *British Journal of Surgery*, 1919, Vol. 7, p. 195.

objections raised against the method when applied to goitre with dyspnœa, viz., that a very deep narcosis is needed for the introduction of the catheter, and that this may be difficult or impossible when the trachea is much flattened. When dyspnœa is so extreme that the patient's colour is dusky before administration begins oxygen should be given at the same time as the ether. These patients are generally kept under with remarkably little anæsthetic when once anæsthesia has been reached.

When the subjects of thyroid tumour suffer also from *affection of the heart* they require particularly careful handling by the anæsthetist. "Many deaths that occurred at operations on thyrotoxic goitre cases when surgeons began to operate for this disease were due to chloroform on top of an already gravely poisoned heart" (Dunhill). There are three classes of patients of this kind—those in whom the heart has given way after long-standing dyspnœa, those who, without presenting all the symptoms of exophthalmic goitre, yet have cardiac symptoms associated with the thyroid swelling, and thirdly the subjects of true exophthalmic goitre. In the last class we have to deal with both a highly unstable nervous system and a heart that is in danger of exhausting itself by an uncontrollable rapidity of beat, the "run-away heart." The sufferer from exophthalmic goitre often dies suddenly apart from any operation.[1] The disease may cause an acute intoxication, or chronic visceral degeneration which has its most formidable seat in the heart. The psychic element in these is so predominant that they are bad subjects for local analgesia. Omnopon, scopolamine, and atropine should be injected an hour before administration. It is in them that Crile's method of "stealing the thyroid" has been employed with success. Rectal anæsthesia may well be used in a similar manner. The patient is given for several days preceding operation a saline injection *per rectum.* Becoming accustomed to this treatment, she receives on the day of operation, and an hour before it is to take place, the ether injection without being informed that anything unusual is taking place. She becomes quickly unconscious, is operated on and back in bed without there having been any chance of fear adding to the operative risk. In all the patients with cardiac disease a light ether narcosis, either by the drop or the warm vapour method, if rectal is not used, or by intra-tracheal insufflation, provides the safest medium for anæsthesia. The heart's disability must be carefully ascertained beforehand. Dr. J. S. Goodall[2] has pointed out that the degree of myocardial exhaustion present, the amount of dilatation, the

[1] *Brit. Journal Surgery,* Vol. 1, 1913, p. 700.
[2] *Proc. Royal Soc. Med.,* Vol. 13, No. 8, p. 55.

presence or absence of definite myocardial degeneration, and the height of the systolic blood pressure must all be investigated, and that this cannot be adequately achieved without electro-cardiographic and X-ray examination together with mapping out of the field of cardiac response. Local analgesia used in association with preliminary injection of sedatives has been warmly upheld by some authorities for these patients.[1] Kocher, of Berne, whose experience is perhaps unrivalled, is a strong supporter of local analgesia for all goitre operations, but it is permissible to doubt whether he has had the best forms of general anæsthesia at his disposal. Mr. James Berry[2] states that he is using local less and less, and general anæsthesia more and more. "The psychic effect on a very nervous patient may be more injurious than that of a general anæsthetic."[3] Mr. Romanis has greatly lessened the mortality by using local anæsthetics and twilight sleep.[4] He disapproves of intra-tracheal methods because of the necessary manipulation of the neck.

The surgical treatment of *acute empyema* is generally best carried out under an anæsthesia produced by chloroform and oxygen. The lung of the comparatively sound side is often itself affected by a certain amount of bronchitis, and ether is to be avoided. The general condition, however, may be so grave as to make it advisable to use ether instead of chloroform with the oxygen, or in adult patients so affected nitrous oxide and oxygen may be employed. Narcosis should not be deeper than just enough to abolish the corneal reflex when the skin incision is made. After this very little anæsthetic is given, and it is an advantage if the patient coughs as soon as the pleural cavity is opened. From that time no further anæsthetic is generally needed. The position of the patient is important, for if his sound side is in any way hampered risk is involved. Should the empyema burst into the bronchus of the sound side, rapid asphyxia is likely to follow the accident if this side is lowermost. Consequently the patient is to be laid as far as possible on the affected side and rolled over only so much as is necessary to give the surgeon his desired access. By placing the patient well to the edge of the table this can generally be achieved without any undue embarrassment of the unaffected lung. *Chronic empyema* is generally to be treated on usual lines as regards the anæsthetic. There is commonly no dyspnœa, and the short operation necessary can be carried out under gas and oxygen or gas and ether. Some surgeons prefer local anæsthesia for all

[1] See an article by the late Mr. Rouquette, *Lancet*, 1918, Vol. 2, p. 776.
[2] *Proc. Royal Soc. Med.*, Vol. 13, No. 8, p. 53.
[3] *Lancet*, Sept. 2, 1911, p. 672.
[4] *Ibid.*, March 11, 1922, p. 471.

empyema operations. It is certainly often of great advantage in acute cases. Operations in the removal of *a large number of ribs* to allow falling in of the chest should be carried out under local anæsthesia.

Short operations upon *the breast* can generally be performed under gas and oxygen with the aid of small amounts of ether when necessary. The complete operation, as for carcinoma, may be dealt with in the same way. Usually, however, this is not the best method to employ for extensive procedures on the breast because of the very free oozing that accompanies the anæsthesia of gas and oxygen. C.E. mixture followed by a mixed vapour of chloroform and ether from Shipway's apparatus gives very good results. Moreover, the anæsthetic is given in this way with far less interference with the surgeon's arrangements than if a face-piece has to be held or fixed on to the patient's face, as it must be with gas and oxygen. A sterilized towel over the patient's face, which is turned away from the surgeon, completely cuts off the anæsthetist, whose hand is beneath it. Either a metal frame covered with domette or a tube in the side of the mouth is steadied by this hand, which serves also to keep the face on the side and the lower jaw forward. The anæsthetist's other hand works the pump of the apparatus and may from time to time lift the towel by its under surface so as to afford a view of the face. During the skin incisions a vapour is supplied mostly of ether, but then during the long dissection of the axilla this is largely replaced by chloroform. In this way both hæmorrhage at the time and undesired after-effects are reduced to a minimum. The amount of shock caused by the complete operation may be severe. The anæsthetist watches carefully the patient's condition and supplies ether more and chloroform less as he appreciates the onset of shock. The more loss of blood that is allowed the less anæsthetic does he find it necessary or advisable to supply ; a very weak vapour suffices during the greater part of the proceeding. The amount of dressing and bandages applied after this operation renders coughing difficult for the patient. It is therefore of great importance that everything should be done to lessen the chance of bronchitis or any lung affection. For that reason the amount of ether used is kept as low as possible and atropine is always to be given beforehand.

Operations upon the *limbs*, unless they deal with fingers or toes, do not require deep narcosis, and are generally well suited in adult patients by nitrous oxide and oxygen. The many slight operations on bones, for removal of sequestra, laying open sinuses, etc., which war surgery provided in such great numbers, were, in fact, the especial field in which this method of anæsthesia proved

of the greatest service. Frequently the proceeding had to be repeated more than once on the same individual, and it was of much advantage to be able to use an anæsthetic which left no unpleasant after-effects. Again, the patients who have to undergo these repeated operations are often in poor condition owing to long-standing septic absorption. It is greatly to their benefit if toxic anæsthetics such as ether and chloroform can be totally avoided. Amputations are included in the above remarks. For those involving the greatest shock, as, for instance, amputation at the hip joint, it is well to use some ether in addition. The added stimulation of a small amount of ether helps, I believe, in carrying the patient safely through the ordeal. At any rate, I have been disappointed by the severity of the shock produced by an amputation at the hip joint performed under "gas and oxygen" alone. Small children, who are not suitable subjects for gas and oxygen, should be given open ether. Short operations upon the limbs of those who from their general physique do not appear to offer a favourable field for gas and oxygen may well be performed under gas and ether as described on p. 234.

Abdominal operations are distinguished from others in this, that the site of operation is affected by the movements of respiration. Consequently the condition of the muscles concerned in respiratory movement bears directly upon the surgeon's facilities. Any undue contraction or abnormally vigorous movement of the abdominal wall will impede the surgeon during an abdominal operation, though such muscular phenomena would be of little import were the operation placed elsewhere. It is obvious, then, that something more is demanded of the anæsthetist than the mere relaxation which suffices perfectly for an operation, say, on the breast or on a limb. Furthermore, these abdominal operations often involve the manipulation of most sensitive structures. Vigorous reflex protective contractions are thus very easily excited. Pulling on such organs as the uterus or prostate, dragging or even cutting of the parietal peritoneum, manipulations in the immediate neighbourhood of the diaphragm, all these proceedings call forth most active reflex contraction of the muscles of the abdominal wall, and to control this effectively tests all the anæsthetist's knowledge and skill. The greatest difficulty is met with in operations upon the upper abdomen. To secure flaccid recti during the removal, for instance, of a small, contracted gall-bladder surrounded by dense adhesions deep in a fat belly taxes all the resources of the anæsthetist. The muscles in such a patient may have been chronically contracted for years over the underlying lesion, and if in addition the costal arch is steep and narrow and the diaphragm is acting vigorously the obstacles to providing

the surgeon with easy access to his object are readily appreciated. For conditions such as these gas and oxygen rarely suffice. In fact, it may be said that, used alone, they are scarcely ever suitable for operations on the upper abdomen. If the surgeon employs local anæsthetics freely, then gas and oxygen may answer well; if he does not, the gases will most certainly need to be passed through ether or C.E. mixture to a greater or less extent in order to get the necessary quiet of the abdominal wall. It is maintained by some that gas and oxygen should be used for abdominal operations because of the great gain to the patient in remaining free from vomiting afterwards. Thus the chances of recurrent hæmorrhage and of bursting stitches are greatly diminished. On the other hand, it may be urged that if this freedom from after-effects is only gained at the expense of extra difficulty on the table, whereby the surgeon has to employ force in retracting the muscles and a much longer time in operating than if the muscles are slack, then the gain to the patient is more apparent than real. More injury, it is said, is inflicted upon him by the difficulties of the operation than is saved him by the ease of his recovery afterwards. Moreover, it is held by some surgeons that a small amount of vomiting after operation lessens the chance of adhesions forming. The anæsthetist must aim at the golden mean. Both in the interests of the patient and of the surgeon his first duty is to provide absolute facility for the surgeon's manipulations, provided the safety of the patient is not endangered. When that facility can be provided only by absolutely relaxed muscles he must render the muscles flaccid if it is possible. At the same time it is obvious that, supposing the surgeon is able to operate perfectly, when the muscles are allowed to retain their tone to some extent it is all the better for the patient. Thus the anæsthetist's action and the patient's welfare depend a good deal on the surgeon's abilities in this particular. One surgeon, in fact, will operate quite happily and well with an abdomen a little tight under gas and oxygen when another would complain that the same patient was "stiff as a board," and would wait until the muscles were softened by ether or chloroform. Complete relaxation of the abdominal muscles involves some depression of the patient's vitality, lowering of blood pressure, and the metabolic deficiencies associated with shock. There are anæsthetists who hold that it is unscientific and bad practice to produce such a condition. Yet unless they can persuade surgeons to adopt methods which make operation easy, though muscles are not relaxed by general anæsthetics, or else to be satisfied with an inconvenient condition during operation, the opinion of such anæsthetists cannot be put into

practice, however theoretically sound. In actual practice the reasons advanced against complete relaxation have weight only in the case of long operations or of operations upon persons already much enfeebled. For the average abdominal operation on an individual in fair health **complete relaxation may and should be produced by general anæsthesia,** or by a combination of general and local anæsthetics, without endangering the patient's safety. By this measure the surgeon's facilities are increased to the utmost and the operation time proportionately reduced. Whether this relaxation should be obtained by spinal analgesia rather than by full narcosis depends on the nature of the patient and the surgeon's preference. Many patients are obviously ill suited for spinal analgesia, which can never be said to be an entirely painless procedure. There is always at least the pain of puncturing the dura ; and some surgeons are handicapped by the knowledge of the patient's consciousness. This consideration weighs also against operating under local analgesia. When this is resorted to for abdominal work the patient must be freely treated beforehand with sedative injections. Certainly very good results have been obtained in this way by the use of omnopon hypodermically and local anæsthetics. Gray [1] uses omnopon ($\frac{2}{3}$ gr.) with scopolamine ($\frac{1}{150}$ gr.) injected intra-muscularly into the buttock an hour and a quarter before operation. Sometimes a second injection of smaller quantity is required. He finds the method of omnopon and scopolamine in conjunction with local anæsthetics especially advantageous in extensive operations on old subjects. There is usually sleep for about six hours after operation, or in the absence of sleep no pain is felt for about that length of time. The necessary facility can be given for all abdominal operations by the **proper use of C.E. mixture,** which may in many instances be replaced by open ether for the greater part of the operation. It is but rarely that vomiting is a serious matter after the use of these anæsthetics on a properly prepared patient who is also correctly treated afterwards. Such treatment usually includes rectal administration of saline containing at first bromide and aspirin and later glucose. In very easy subjects, including most children, "gas and oxygen" answers well for the ordinary *appendix* operation, as it does for the radical cure of hernia. The greatest advantage is obtained from this anæsthetic, however, when it can be used for long and trying procedures such as considerable resections of bowel, or colotomy combined with excision of rectum. It will rarely suffice unaided for these operations, even when hypodermic narcotics have been freely used before. Yet, even if the surgeon does not employ local anæsthetics, the

[1] *Lancet*, Sept. 2, 1911, p. 672.

amount of ether that the anæsthetist needs in conjunction with his gas and oxygen is so very much less than would be required if ether were mainly depended upon that there is a great gain in the after-condition of the patient. After a successful administration of gas and oxygen for a long abdominal operation the patient recovers consciousness very rapidly and is able soon to take stimulating nourishment by the mouth. This in itself is a great advantage, apart from the boon of being free from sickness, for shock is more preventable than when the patient is long unconscious and cannot be given anything by the mouth. In administering any anæsthetic for an abdominal operation the paramount necessity for a perfectly free air-way and sufficient aeration of the patient must never be overlooked. The least cyanosis or deficiency of oxygen will be a potent factor in causing rigidity of muscles. To secure a soft abdomen it is often not more anæsthetic, but less anæsthetic and more oxygen that are wanted at the hands of the inexperienced. The inconvenience due to incompletely relaxed muscle is perhaps most noticeable when the surgeon begins to close the peritoneum. Especially in the upper abdomen, after gall-bladder operations, for instance, there may be the greatest difficulty in getting the two sides of the divided peritoneum together. The recti may be quite flaccid, but the pull of diaphragm and transversalis muscles may remain formidable. Sometimes a little help will be got by having the thighs flexed and the chest raised. When an air-cushion has been in use behind the lower ribs during operation this must be emptied or removed to help the closing of the abdomen.

For *prostatectomy* thorough flaccidity of the abdominal muscles is essential. The manipulations may be trying enough for the surgeon's fingers even at the best, and if in addition to working in a confined space deep in the pelvis he is embarrassed by the walls of that space gripping his wrist and hand, his task becomes arduous in the extreme. Profound narcosis is necessary to get the required relaxation, and yet the subjects of the operation are often men of advanced age in no condition to stand deep anæsthesia with safety. Often they are either bronchitic or afflicted with secondary renal disease or arterio-sclerosis. Consequently the aid of spinal analgesia is generally to be sought for this operation. It need not, and generally should not, be relied upon alone, but merely in order to produce the required relaxation without the necessity for large amounts of the general anæsthetic. C.E. mixture or chloroform and oxygen are usually the most appropriate anæsthetics to employ, and the spinal puncture may be made after unconsciousness has been secured if there is good reason to spare the patient the slight pain and inconvenience

which it causes. In the presence of chronic bronchitis, obesity, and fatty heart the operation of prostatectomy is most safely carried out under spinal anæsthesia with the aid of very little C.E. and oxygen. The Trendelenburg position is then to be avoided. The same principles apply when the operation is performed upon those suffering from cardiac lesions.[1]

Cystoscopy of a tubercular bladder is another example of operation in which straining is extremely difficult to avoid unless spinal analgesia is employed.

In the operations of *gastro-enterostomy* and of intestinal *anastomoses* of various kinds the anæsthetist must pay careful attention to the different degrees of narcosis appropriate to the different stages of the operation. In this way he will save the patient from inhaling unnecessary amounts of anæsthetic and will to that extent lessen his after-sickness and his risk of shock. For opening the abdomen and drawing forward the viscera to be treated deep narcosis is essential. During the performance of the anastomosis, on the other hand, very little anæsthetic is required because of the insensibility of the parts. For returning these into the abdomen and for closing the peritoneum deep anæsthesia is again necessary, and so the anæsthetist must keep himself aware of the stage that the surgeon has reached in order that the anæsthetic may be freely given in time for the necessary relaxation to be present when it is needed. Narcosis, in fact, must be increased before the anastomosis is actually completed. Then when the abdominal walls are pulled upon or retracted for replacing the viscera there will be no undue stiffness in them and the peritoneal edges will easily be brought together.

In operations upon the *gall-bladder and gall-ducts* a deep narcosis is generally necessary throughout. The difficulty of providing ease for the surgeon is often enhanced by the air-cushion or sand-bag placed under the lower ribs to push forward the site of operation, which stretches the abdominal wall. This should be withdrawn before the closing of the abdomen begins. The necessary anæsthesia is generally best secured by C.E. mixture and open ether. When the latter alone is relied upon, it may be necessary to push it to the degree described in connection with the operation for dissecting out tonsils. To keep this form of narcosis going over a considerable period of time is dangerous because of the subsequent reactionary shock, and it will generally be found wiser in the very long cases to use C.E. for the middle portion of the operation.

Operations on the *kidney* are managed in the same way. The anæsthetist must beware of the shock which may accompany

[1] *Brit. Med. Journal*, Jan. 15, 1921.

traction on this organ. Full ether anæsthesia is generally most suitable. When a lateral position is used, Carter Braine's arm-rest (Fig. 42) must be in position to support the upper arm and give the chest scope to move freely with respiration. When the prone position is used, as preferred by some surgeons, the anæsthetist has to take precautions that he can apply the mask to the face without undue twisting of the neck. Often he will need a small sand-bag behind the shoulder on the side towards which the face is turned.

The operation of *circumcision*, apparently trivial, has often been associated with disaster due to the anæsthetic. This has occurred through producing too profound a narcosis in infants. No attempt should be made to render the infant motionless with chloroform; open ether should be used and the thighs controlled by an assistant or nurse, so that little anæsthetic is given after consciousness is abolished.

Long operations for *removal of the uterus*, Wertheim's operation, removal of fibroid impacted uterus, of adherent Fallopian tubes and the like, are proceedings which require full relaxation of the abdominal muscles. They are also apt to be attended with severe shock. The use of spinal analgesia in conjunction with light narcosis is often of great advantage, particularly as in these operations local anæsthetics cannot easily be used with sufficient thoroughness to ensure relaxation. When spinal injection is not employed, deep anæsthesia must be secured by C.E. mixture and open ether; gas and oxygen is rarely applicable, although often sufficient for a simple ovariotomy.

Gas and oxygen often answers very well also for *Cæsarean section*, and when this is performed on account of albuminuria, must be the agent chosen, unless spinal injection is preferred. When gas and oxygen is used it is understood that ether is always available, to be added, if necessary, at any moment. A few breaths will probably be needed whenever, as in patients with albuminuria, morphia has not been given beforehand. Gas and oxygen for Cæsarean section has the special advantage over deep ether or chloroform anæsthesia that the baby when delivered is quite unaffected by the anæsthetic.

Operations upon *the rectum* and its neighbourhood are best carried out under ether, which has especial advantages on these occasions for two reasons—firstly, reflex effects on the respiration are commonly evoked and may easily give rise to danger in the presence of chloroform, and secondly, although the operation may be of short duration, a very deep narcosis is desirable. For all the short operations in this part of the body "gas and ether" is very suitable if the patient is otherwise well fitted for it. In

operations for fissure, for a few internal piles, for polypus, or for external hæmorrhoids, the amount of ether needed is not great when full anæsthesia has been obtained, and nitrous oxide may be used continuously after the manner described elsewhere (reference to *new gas and ether*). For excisions of the rectum and equally prolonged operations open ether is preferable. On suitable subjects these long operations are well performed under "gas and oxygen" with very little ether, the surgeon employing local anæsthetics. The method offers the great advantage that the patient can be fed and given stimulants by the mouth very soon after he is back in bed. When the subject is feeble this is of such moment after a severe rectal operation that his chances are greatly enhanced if the anæsthetic can be limited to "gas and oxygen" aided by local analgesia. Moreover, there is none of the reactionary shock that may follow prolonged inhalations of ether, while his condition during operation is safer than if the necessary narcosis were obtained with chloroform. Mr. Lockhart Mummery tells me that he prefers "gas and oxygen" and local anæsthetics for severe rectal operations to any other method, and has abandoned the use of spinal analgesia in its favour. The combination of preliminary alkaloids with *sacral anæsthesia* has been highly successful in these cases.

Anæsthesia in Labour

For the *normal confinement* little, if any, anæsthetic is needed during the first stage. Indeed, many patients are out of bed for a great deal of this period, during which they often find walking about less harassing than lying down. The primipara or the extra-sensitive woman may need some help. This is often given nowadays by hypodermic injection, which method is more fully dealt with later. If a general anæsthetic is used it is given in minimal doses, no attempt being made to induce surgical anæsthesia. The anæsthetic is given only when a pain comes on, and is stopped directly the pain is over. Chloroform at this stage can be perfectly well administered by the patient herself if a Junker's apparatus is employed. The bottle should hang to the back of the bed, and the patient is shown how to apply the face-piece and squeeze the pump. This she is allowed to do directly a pain begins, stopping when it ceases. The distraction of busying herself with the pump and face-piece is of itself an advantage to her. Should she render herself unconscious, a very unlikely occurrence, the pump will fall away from her hand. When the pains grow stronger, and in the second stage, the anæsthetic should no longer be left in the patient's hands. The anæsthetist will now often find it an advantage to keep the patient bemused

even between the pains. Full anæsthesia is still not aimed at, and it is only during the pains that the chloroform is given at all freely. When the painful period is at its climax with the head passing over the perineum, then full narcosis may be allowed for a minute or two. Even then, of course, there is no need to abolish the corneal reflex. Used in this sparing manner chloroform can, without retarding the process of delivery, yet render it almost entirely painless. Moreover, it appears to be remarkably safe in spite of the intermittent nature of the administration. For this there are probably two reasons—firstly, the attitude of the parturient patient is peculiarly favourable to anæsthesia, as is that of any individual actually in pain, and secondly, the narcosis aimed at being so light, there is no danger at all of overdose or the toxic effect of too concentrated a vapour. When an *obstetric operation* is required the anæsthetist must be guided by his usual principles. For the deep narcosis necessary he will no longer rely on chloroform, but will use ether just as he does at other operations. It is perfectly well and safely taken by the patient, who is probably already to some extent under the influence of chloroform. If, however, when the anæsthetist is called in to help at an obstetric operation the patient has hitherto had no anæsthetic at all, he will act as in any other surgical case. "Gas and ether" can perfectly well be used, but more often the arrangement of the bed and room renders the simplest apparatus the most suitable. A small quantity of C.E. mixture or of chloroform on an open mask followed by full narcosis with open ether is generally perfectly appropriate. In using anæsthetics for confinements two main considerations must be borne in mind—firstly, the effect of the drug on the progress of labour, and, secondly, its effect on the child. With regard to the first point, it may be said that, used with proper discretion, chloroform delays very little, if at all, the duration of a normal labour. The intervals between the pains may be prolonged if on their occurrence full narcosis is obtained. This, as we have pointed out, should not occur. On the other hand, the progress of the labour is actually expedited during what would be its most painful period, for the patient who is analgesic with chloroform will not resist, and may actually assist, expulsive efforts when the head passes the perineum. Another advantage gained at this time is that if delay is desired in order to gain full stretching of the perineum the anæsthetist can help in securing this by prolonging the narcosis at each pain. The use of *nitrous oxide and oxygen* at confinements in preference to all other anæsthetics is warmly advocated by some.[1] The

[1] "Nitrous Oxide-Oxygen Analgesia and Anæsthesia in Normal Labour and Operative Obstetrics" (National Anæsthesia Research Society).

arguments advanced in favour of this measure are that, the gas being entirely non-toxic, the mother's convalescence is never retarded and the infant cannot be injuriously affected. Secondly, it is urged that by "gas" alone can analgesia be quickly obtained and quickly recovered from, and that this is exactly what is required for the intermittent pains of labour. When nitrous oxide is employed for confinements the anæsthetist aims at procuring analgesia, not anæsthesia, with every pain. In order to secure this he applies the face-piece at the earliest possible moment of a commencing pain. At the end of the pain the face-piece is removed, and no attempt is made to preserve analgesia between the pains. During analgesia the patient is susceptible to suggestion, and will co-operate by bearing down during a pain. This she is the more ready to do because the effort does not hurt. When the head is passing over the perineum gas and oxygen rarely suffice. At this period they are administered with the intention of procuring true anæsthesia, not merely analgesia. Even so it is often necessary to supplement them with some ether in order to keep the patient really still and free from pain. Similarly, when the confinement is abnormal and an obstetric operation is required, nitrous oxide and oxygen alone do not provide a suitable or sufficient anæsthesia. For complete success with nitrous oxide and oxygen at a confinement much depends on the co-operation and temperament of the patient. Frightened, neurotic, or hysterically inclined women cannot be successfully treated by intermittent analgesia. With these the analgesia must be kept up between the pains during the second stage, if, indeed, it is not necessary to procure true anæsthesia. The anæsthetist guides his normal patient on the path of analgesia by avoiding excitement on the one hand and complete unconsciousness on the other. The first arises from too free, the second from too sparing, dilution of the nitrous oxide with oxygen. It is wise when the first inhalation is given to procure a light anæsthesia. This gives the patient confidence and leads to success later with a merely analgesic condition. The patient must be encouraged to breathe the gases freely immediately the face-piece is applied. This is at the earliest moment when the onset of a pain is appreciated. If the pain is fully realised before the inhalation begins the beneficial effect of taking the gases is largely discounted, for the patient's memory is active for that part of the pain which was felt, although a much greater amount was perhaps prevented. It is obvious that inconveniently large amounts of nitrous oxide may be required in the course of a long confinement. In order to obviate this many anæsthetists employ re-breathing to a considerable extent. When proper regard is paid to the physique of the par-

ticular patient, when the bag is emptied sufficiently often, and when oxygen is used in proper quantity, this practice appears sound. Some authorities, however, among whom must be mentioned Ferguson, are opposed to re-breathing when nitrous oxide and oxygen are used in obstetrics. They regard the practice as dangerous to the baby. Ferguson states [1] that "air and nitrous oxide are less dangerous than re-breathing, but slightly more dangerous than when oxygen is used." The use of nitrous oxide at confinements appears to be entirely innocent of encouraging postpartum hæmorrhage or of interfering in any way with lactation. Statistics have been published showing that the average duration of labour is shortened by use of the gases both for primiparæ and for multiparæ, and that the liability to laceration is less than without anæsthetics.

The *hypodermic injection of narcotics* for reducing the pains of labour or obliterating the memory of them has much to recommend it. When this process is relied on solely and without the aid of true anæsthetics it is generally in the hands of the accoucheur. Nevertheless, the anæsthetist should be familiar with "twilight sleep," because he may have to help a patient who is under the influence of the drugs used, or he may be asked to superintend the administration of them. The object aimed at by this process is not true narcosis, not even painless childbirth, but a degree of amnesia which obliterates all memory of the pains due to uterine contractions and the stretching of the genital passages.[2] The sensation of labour is present, but to a diminished degree, and afterwards the woman remembers nothing at all of the process. For the best results the presence of the accoucheur or anæsthetist is necessary from the first injection to the completion of the labour, and this is in practice a drawback to complete employment of the method. When a nurse fully trained in the injections and their results is available, however, the medical man may absent himself for considerable periods of time. The drugs used are morphia, or omnopon, and scopolamine. According to Gauss, who in 1906 was the first to publish an extensive series of cases, the technique should be carried out as follows. The first injection is given to primiparæ when the pains occur regularly every few minutes and are beginning to be objectionable, to multiparæ directly labour starts. This injection consists of morphia gr. $\frac{1}{4}$, scopolamine gr. $\frac{1}{150}$. The second dose is given one hour after the first. This consists of scopolamine alone ($\frac{1}{400}$ to $\frac{1}{500}$ gr.), unless there is extreme restlessness on returning consciousness,

[1] "Nitrous Oxide-Oxygen Analgesia and Anæsthesia in Normal Labour and Operative Obstetrics" (National Anæsthesia Research Society), p. 51.

[2] Comyns Berkeley in Webb-Johnson's "Twilight Sleep."

when $\frac{1}{8}$ gr. of morphia is added. For further doses reliance is placed on the memory test. The aim of "twilight sleep" is not analgesia, but amnesia. Symptoms of feeling the pains may arise, but there is no memory of the feeling. The memory test is applied half an hour after the second injection. Some ordinary article—a handkerchief, for example—is shown to the patient. Half an hour later she is asked what was shown to her. If she can say what it was the scopolamine injection is repeated. If amnesia is present and she cannot tell what was shown to her, she is questioned again in half an hour's time, no injection being given until she succeeds in remembering what was shown her half an hour before. The patient should be in a quiet, darkened room, and her ears should be plugged with cotton-wool soaked in oil. She should lie on her side and should be catheterized if necessary. Although there is considerable difference of opinion among British gynæcologists as to the advisability of using these injections in place of anæsthetics, it seems to be generally agreed that with proper supervision of dosage they are not injurious to either mother or child. The charge of producing asphyxiated babies brought against the method has been shown to be baseless if the morphia is duly restricted to the early stages of labour. Occasionally a woman shows idiosyncrasy towards scopolamine, becoming restless or violent. The treatment must then be abandoned in favour of chloroform. "Twilight sleep" has often to be assisted during the passage of the head by inhalations of a general anæsthetic. Many obstetricians, without attempting to procure true "twilight sleep," use injections of morphia and scopolamine in the early stages of labour, especially for primiparæ, and combine these with a later use of general anæsthetics, just as the anæsthetist for surgical cases uses preliminary narcotics before administrations.

B. The Nature and State of the Patient

In choosing the most appropriate anæsthetic and method of administration many circumstances have to be taken into account. In private practice, for example, the anæsthetist will often have to do the best that circumstances permit, although this may be very different from what he would choose if unhampered. The limitations which a large bed in a small room impose upon him may have to be reckoned with, or other similar inconveniences may restrict his use of apparatus really necessary for the best form of anæsthesia in the particular case. Again, the practitioner may himself be unfamiliar with the use of some methods and may be confronted with a patient whose operation demands the use of one of them if the best possible is to be achieved.

In such a case it is best for a man to use the method at which he is expert rather than venture on one with which he is unfamiliar. In laying down the rules to guide us in choosing an anæsthetic we shall assume no such limitations, but discuss the matter as though the anæsthetist had both the opportunity and the ability to use whatever method was actually most desirable for the operation to be performed. The main considerations to be borne in mind are the **safety of the patient,** the **convenience of the surgeon,** and **complete and comfortable post-operative recovery.** In order to secure these we must have regard to the nature and state of the patient, both physical and mental, and the site and nature of the operation. The latter we have already considered in detail.

The Nature of the Patient.—In making his ordinary examination the anæsthetist of experience rapidly gleans a comprehensive opinion of the subject before him. He notes the physical vigour or feebleness, the excitable or phlegmatic temperament, the habitual sobriety or indulgence, the cheerful or despondent aspect of his patient, and he determines his line of action in accordance with his observation. The highly nervous or frightened he will coax into unconsciousness with plenty of soothing talk and a very gradually administered vapour. Often with such folk it is helpful to let the patient hold the mask for herself, for she fears above all things "being rushed." Gradually she is induced to lower it towards her face and eventually to resign both it and herself. The ordinarily sensible man or woman, on the other hand, will often prefer to be rendered unconscious as quickly as possible, and the anæsthetist accommodates the patient by using nitrous oxide or ethyl chloride for the induction of anæsthesia, employing but a few words of quiet encouragement and confidence. *The child* he will be at extra pains to make friends with. He will show him what is going to be done, making it obvious that there is going to be no deception and that the whole performance will be quite a cheerful one. It is very rarely that there is trouble with children if they are treated openly and gaily, if they are old enough to understand. Younger children must be quietly and quickly anæsthetized without more ado, the hands being held preferably by some one to whom the infant is accustomed. Open ether preceded by ethyl chloride on the open mask is generally best. In administering anæsthetics to infants two facts must be borne in mind. Firstly, the shallow respirations make it appear that a great deal of anæsthetic is required to produce narcosis because the time spent is considerable. Secondly, only very profound narcosis can completely overcome the liveliness of the autonomic system and the reflexes of the infant. This

profound degree should rarely be reached except for abdominal work—for instance, operations for congenital pyloric stenosis.

Age does not materially affect the choice of anæsthetic, except that infants cannot conveniently inhale nitrous oxide. It used to be maintained that chloroform should always be chosen for those under six and over sixty. No such line can be drawn, and certainly chloroform should not be made the routine anæsthetic for children any more than it should for adults. Ether is perfectly well taken by children, and has as great an advantage in point of safety with them as it has with adults. Nor need the old be limited to chloroform only. Their physical condition frequently permits nitrous oxide or ether to be used for them with the best results, and their mere years should not influence us to their detriment.

Sex is not of great moment. Generally speaking, women are easier subjects than men ; but a very muscular woman will often prove more troublesome than a feeble man. The presence of the *menstrual period* is generally regarded as an indication to avoid administration of an anæsthetic. No doubt emotional disturbance is more easily excited at this time, and therefore, if there is free choice, another day is to be preferred. Emergency operations, however, have constantly to be done on patients who are menstruating, and then it is extremely rare to find untoward symptoms referred to this condition. And it is not held as a cause for choosing one anæsthetic rather than another.

Even to-day many people are frightened at the idea of unconsciousness, ignoring the fact that they are unconscious every night of their lives, and the anæsthetist must bear in mind the patient's attitude towards the process and must speak and act towards him with due kindness and encouragement. Patients died of fright before the stroke of the knife in pre-anæsthetic days, but, in spite of the enormously increased number of operations, such a death before the anæsthetic has been begun is of the greatest rarity, showing that the fear of anæsthesia which still exists is less intense than the former dread of pain. In many nervous, highly-strung individuals this psychic element requires special treatment by preliminary use of sedative drugs in order to get the best anæsthesia at operation and recovery afterwards. Such persons should be seen by the anæsthetist before the day of operation. Much can be done to quiet their minds by listening to and allaying their fears and suspicions. The most elaborate steps to overcome the untoward results of fear are those taken in Crile's method, in which a series of rehearsals of the process, but without the actual anæsthetic, are practised on several occasions before operation (p. 268).

It is impossible to describe all the different types of patient ;

they are as various as men and women. Certain distinguishing features may, however, be recognised which play a dominant part in determining the reaction to anæsthetics. Thus, contrary to popular ideas, the best subjects for anæsthesia are not the strong, robust individuals in perfect health. Generally speaking, the more muscular the individual the more difficult, and therefore in some ways the worse, subject is he for anæsthesia. This is due, of course, to the greater trouble which arises in his case from muscular rigidity and spasm than from the same phenomena in people of feeble muscular development. The likeliness of such spasm, its formidable nature if aroused, and its deterrent effect upon the respiration are prime reasons for avoiding chloroform for the induction of anæsthesia in the strong individual. Where a rapid induction is desired for such persons ethyl chloride is the best anæsthetic to choose, and where a slow one open ether aided, if necessary, by the C.E. mixture. The two latter are the best agents to rely on for maintaining the narcosis. The kind of individual alluded to here is met frequently in naval and military practice and among athletes of both sexes. When to physical qualities of the kind alluded to above habitual freedom in the use of alcohol and tobacco is added we get the patient who offers formidable resistance to the onset and maintenance of quiet anæsthesia. In such persons there is much tendency to coughing and straining as well as to muscular rigidity in the early stages. Moreover, when narcosis is fully established there is unusual tendency to reflex movement. It may be almost impossible to keep a chronic alcoholic perfectly still, during rectal or peritoneal manipulations for example, however profound the narcosis. Larger quantities of anæsthetic may not be needed, as Snow maintained they were not, to induce unconsciousness, but the difficulty of abolishing reflex sensibility even with heavy doses of narcotic is very great. Patients of this type can rarely be well managed with nitrous oxide either for long or for short operations. They generally require full dosage with ether, and this must often be supplemented with C.E. mixture or chloroform. For quite short operations ethyl chloride is far better suited to them than gas. Preparation by several days of light diet, greatly reduced consumption of alcohol, and bromides is helpful. Examples of this kind of patient are provided by hunting men in private practice and by draymen in hospital. They are rarely sick after anæsthetics and often enjoy the whole process, being from their own point of view as favourable subjects as they are difficult from the anæsthetist's outlook. The combination of an active open-air life with free use of alcoholic drinks makes difficult subjects for anæsthesia.

Very fat persons are generally unfavourable subjects for any closed form of apparatus. They require free aeration, and for major operations are generally best managed with C.E. mixture. For minor operations they can be well treated with nitrous oxide and oxygen, the latter being freely used. At the other end of the scale from the robust individual, accustomed to exercise in the open air and the use of alcohol, comes the pale, meagre, abstemious and poorly fed female met frequently in all big cities, where she may serve in a shop or act as typist, secretary, or governess. These are the people who provide the easiest field for narcosis. With them care is needed, not so much in order to procure the necessary relaxation, but in order to avoid overwhelming the patient. They are good subjects for nitrous oxide and oxygen even for major operations, and when that is not suitable will be easily managed with open ether. It is rarely necessary to use ethyl chloride or chloroform at all, and if, as often happens, there is considerable anæmia, these agents should be entirely avoided. For persons in ordinary health and with no extreme characteristic, physical or mental, we may say that the general principle is that nitrous oxide and oxygen should be used for most short operations. This should be chosen because it is undoubtedly the safest general anæsthetic at our command under these circumstances. In longer operations its position is not so pre-eminent, but even for major surgery it should be used whenever suitable because of the comparative freedom from after-effects. For most abdominal surgery it is not, unaided, the best anæsthetic, but here it can often be used with great advantage if the surgeon will use local anæsthetics in conjunction with it. If he is averse from this, then the anæsthetist will often have to supplement the nitrous oxide with ether or C.E. mixture. When nitrous oxide and oxygen are not to be chosen, as may be the case for various reasons, open ether should be next favourite for most major operations, and if this is not suitable, then the C.E. mixture. Chloroform should be the last choice for ordinary operations in persons of normal health and condition.

We must now see how our choice of anæsthetic is affected by various **abnormal conditions in the patient.** People who are very ill, from whatever cause, are generally amenable to anæsthetics. They are mentally not opposed to the process, and they are physically more susceptible than those in robust health. Consequently the kind of difficulty which we described in the case of the muscular healthy individual is not encountered in the chronic invalid, and rarely in the patient afflicted with some serious acute illness, who might otherwise have been a difficult subject. With these people anxiety is less likely to arise from the

difficulty of securing the desired anæsthetic effect than from the ease with which their enfeebled or toxic systems may be overwhelmed. We should be most profoundly influenced by *affections of the respiratory system.* Apart from disease, *abnormality in shape or unusual narrowness* of the upper air passages influences the way in which an anæsthetic is inhaled, and determines the method by which it should be introduced. A high, narrow palate with narrow nasal passages, common conditions following naso-pharyngeal obstruction in childhood, renders the patient an unfavourable subject for all closed apparatus. Gas and oxygen may be used in such people for quite short operations, but it does not generally give good results if used for long ones. " Gas and ether " is as a rule to be avoided, and, generally speaking, major operations are best performed under C.E. mixture. When ether alone is used it must be preceded by atropine, and is best given as a warm vapour. There is unusual tendency to the secretion of mucus and to coughing in these narrow-throated subjects, and therefore everything likely to cause local congestion is best avoided. It is with these patients that the insertion of a small prop between the teeth is so helpful, for there is often difficulty with them in keeping the lower jaw forward and ensuring oral respiration. This is essential because they have no adequate nasal passages to permit free breathing through the nose. In extreme cases the upper teeth overhang the lower by a wide margin and the lower jaw is under-developed ; there is then unusual trouble in keeping the jaw forward enough to prevent the base of the tongue obstructing the top of the larynx. Another source of trouble is present in the patients who have *no teeth,* for then the lips and cheeks may collapse or be sucked in at inspiration to a degree that greatly embarrasses breathing unless the nose is very patent. Here again closed apparatus pressing on the face is inadvisable, open methods are to be used, and the mouth kept open by a Doyen's gag, or the lower jaw levered forward by closed tongue-forceps hooked in behind the alveolus or by Longhurst's tongue-retractor (Fig. 32). If these devices are ineffectual, as occasionally happens, a tongue-clip should be used, and a heavy instrument, such as a Mason's gag, should be hung through the loop of the clip to keep the tongue weighted forward (Figs. 4 and 5). Sometimes, in spite of any or all of these measures, the tongue seems too big for the mouth and does not leave enough room between the palate and itself for breathing. When this occurs an artificial air-way must be inserted, unless there is perfectly free nasal breathing, or Silk's nasal tubes may be employed.

Acute catarrh of the upper air passages leads to retching and

vomiting during induction of anæsthesia, and the amount of mucus swallowed makes these symptoms common also during recovery. Closed methods are best avoided, but nitrous oxide and oxygen can be quite well given for very short operations.

Enlarged tonsils, naso-pharyngeal polypus, or any tumour within the mouth may swell during anæsthesia to an extent which embarrasses the breathing. In the presence of these abnormalities an open method is to be chosen. Nitrous oxide or ethyl chloride from a bag enhance the probability of congestion and of spasm in the presence of these swellings. For a simple epulis or other quite small, easily removed tumour within the mouth they may, however, be used just as for tooth extraction. Exception may be made also in the case of chronically enlarged tonsils (see p. 263), which can often be efficiently dealt with under gas and oxygen or ethyl chloride. When an anæsthetic is needed in the presence of acutely enlarged tonsils these agents are to be avoided. When pharyngitis is associated with *acute cellulitis of the neck* (Ludwig's angina) there is often present also acute œdema of the glottis. These patients must on no account be treated with nitrous oxide, for the swelling of the walls of the respiratory tract will easily and rapidly increase to the point of causing acute asphyxia when this anæsthetic is employed. Fatalities have on several occasions followed the use of gas or gas and oxygen with patients suffering from cellulitis of the neck, and the temptation to use this anæsthetic for a patient who is to have merely a rapid incision in the casualty room is an easy trap for the inexperienced. The best anæsthetic to choose is open ether aided by C.E. mixture, and these are to be given gradually with the patient lying on his side and his mouth propped open. These patients are often seriously ill from the toxæmia dependent on their acute local infection. They are then risky subjects for chloroform.

Retro-pharyngeal abscess, a not uncommon condition in poorly nourished children, is a dangerous complication of anæsthesia because of the ease with which the pus may enter the larynx. Safety is best secured by placing the patient in such a position that the larynx is above the level of the mouth, *i.e.*, either in the Trendelenburg position, or else with the neck over-extended over a rolled towel (see section on Tonsils). Open ether may then be safely given. Deep narcosis is generally unnecessary and to be avoided.

Tumours of the neck may embarrass breathing by constricting, flattening, or displacing the trachea. *Goitre* is dealt with elsewhere (p. 266). The anæsthetic for operation on other tumours acting in this way should generally be C.E. mixture or rectal ether.

The case is worthy of mention of a cystic tumour of the neck, dating from birth, operated on in a woman of fifty-four. This filled the neck and pushed up the floor of the mouth so that the tongue could not be protruded, and the appearance of the distended sublingual mucous membrane showing between the lips was most odd. There was, however, no dyspnœa, breathing going on comfortably through the nose. The patient was in the habit of feeding herself by pushing solid morsels round the tongue with the finger. Anæsthesia was gradually induced with chloroform, chosen as least likely to increase the swelling, and took a long time to attain. The neck was stretched over a sand-bag, when respiration immediately ceased. At this time narcosis was light, the corneal reflex being briskly active. The tumour in the mouth was bluish in colour and increased in size. Removal of the sand-bag did not restart the breathing, but when at my request the surgeon incised the cyst in the neck, letting out a quantity of thick, soupy dermoid material, respiration at once began again and continued ordinarily till the end of operation.

Acute affections of the larynx, diphtheria, and mechanical narrowing of the air passages, as from growths, necessitate the use of chloroform. The alternative that is sometimes appropriate is rectal ether. Nitrous oxide and ethyl chloride are to be avoided, and ether, even by open methods, is more apt to increase respiratory difficulty in these patients than is chloroform. Whenever dyspnœa is already present the anæsthetist must be prepared for its exaggeration, whatever agent he employs. Oxygen should in such cases generally be given with the anæsthetic. When tracheotomy is being performed for diphtheria it is not uncommon for the breathing to cease before the trachea is opened ; directly this is effected the respiration can be restarted. Violent coughing often follows the tracheal opening or insertion of the tube, for whatever condition tracheotomy is performed. It is a fortunate fact that patients with severe dyspnœa are generally unusually insensitive, and thus a light degree of narcosis, which is all that can be obtained with safety, suffices for operation.

Acute affections of the lungs, acute bronchitis, active phthisis, and pneumonia are indications to avoid inhalation anæsthesia if possible. It not infrequently happens, however, that an operation must be performed, for instance for the removal of a gangrenous appendix, on a patient suffering from one or other of these affections within the chest. Spinal analgesia is generally the best method to choose if the chest affection is severe. It may, however, be unwise to put the patient into the position necessary for injection, in the presence of pneumonia for instance, and then the best method to adopt is the administration of warmed chloroform with oxygen.

When there are rapid pulse, dyspnœa, and duskiness of the face, anæsthesia is attended with danger of heart failure, and then open ether is safer than chloroform in spite of the lung condition. *Acute empyema* for which a short operation suffices can generally be dealt with by gas and oxygen ; when this is unsuitable, the C.E. mixture is best. Some authorities prefer local anæsthesia for these patients. The general condition of the patient must be fully considered as well as the local respiratory disability, and it may be so grave that for safety on the table some ether may have to be given. The worst case of double empyema in my own experience was operated on under gas and oxygen, ribs on one side only being resected on two separate occasions. This patient had been declared by a famous physician unfit for any anæsthetic. Her breathing ceased when the narcosis was at its deepest, but restarted directly pus gushed from the pleural cavity on incision, and eventually she made a complete recovery.

Chronic bronchitis and emphysema render a patient an unsuitable subject for any closed method of anæsthesia. Respiration is often carried out entirely by the diaphragm, and with this impaired respiratory power all air limitation in anæsthesia is to be avoided. Gas and oxygen is not well taken by these patients, and C.E. mixture or chloroform with oxygen are generally most suitable. When *asthma* is associated with the lung condition there is very apt to be a peculiar expiratory straining with respiration whatever anæsthetic is employed.

Quiescent or healed phthisis is often known to be present in patients for operation. The risk of restarting active trouble in the lung is less if chloroform is used rather than ether for such persons, provided that gas and oxygen is insufficient for what has to be done. Spinal analgesia will often be the safest choice for these patients. In all patients with lung affections it may be said that if there is any cyanosis present oxygen should be used in conjunction with whatever anæsthetic is administered.

Heart affections are popularly and mistakenly supposed to have a great influence on the safety of anæsthesia. When compensation is good and there is neither dyspnœa nor any œdema over the ankles they affect the patient's behaviour under anæsthetics so little that the choice of anæsthetic is unaffected by the presence of organic cardiac disease. It happens frequently that persons who have been warned against any anæsthetic because of heart disease pass safely through major operations performed under general anæsthetics. I have experienced instances of this in patients suffering from nearly every form of organic heart trouble, including mitral stenosis and aortic disease with double murmur. When there is any abnormal rapidity of the

heart, and still more if there is orthopnœa, the case is different. These patients must be so treated that all asphyxia is avoided. They should generally be anæsthetized gradually with open ether, which may often well be preceded by small amounts of C.E. mixture. *Fatty degeneration of the heart muscle* is the organic change which is really most dangerous. Anæsthesia is to be achieved by ether and all cyanosis and asphyxia scrupulously avoided; any respiratory embarrassment is badly borne by patients suffering in this way, and they are bad subjects for long operations or those involving much shock. These remarks apply also to hearts affected by toxic myocarditis and to the feeble muscle of the heart often present after prolonged fever, even when there is microscopically no evidence of myocarditis. The muscle in such cases is, however, soft and thin. The pulse generally improves during anæsthesia when it is irregular or intermittent beforehand from cardiac disease. *Extreme rapidity of pulse* beforehand is often largely due to apprehension, and this cause is removed by the anæsthetic. *Unusually slow pulses* unassociated with cardiac disease have not, in my experience, heralded trouble during anæsthesia, and, generally speaking, persons with unusually slow pulses are more favourable subjects than those in whom the circulation is unusually rapid. Any suspicion of myocardiac weakness or disease should lead to the full investigation described on p. 98.

The rapid pulse of **Graves' disease** is a danger because of the liability in this complaint for the heart to "run away" under anæsthetics till, after almost incredibly rapid beats, it ceases, exhausted. Chloroform is to be avoided with these patients, and open ether is generally the best agent when some operation is to be performed other than that for the relief of the exophthalmic goitre. The treatment for this is described on p. 268. Measures for procuring mental calm are always to be employed when the sufferer from exophthalmic goitre has to undergo operation of whatever nature.

Patients with **pericarditis** sometimes come to operation for relief of the distended pericardium. Narcosis is best secured by gradual administration of C.E. mixture and open ether, and a deep degree should not be reached Oxygen should be inhaled with the anæsthetic.

The presence of **advanced atheroma** or of actual **aneurysm** makes it imperative to avoid all struggling or spasm in the induction of anæsthesia so far as this can possibly be achieved. How best to meet this requirement depends largely on the patient's nature apart from his complaint. Although, generally speaking, closed ether is to be avoided for these persons, I have more than

once induced with gas and ether because it was most likely to, and in fact did, give the smoothest entry into narcosis. Usually C.E. mixture is most suitable. The danger in atheroma cases is that heightened blood pressure and stimulated circulation may cause cerebral hæmorrhage, while in the subjects of aneurysm the same phenomena may lead to rupture. Cerebral hæmorrhage has occurred with fatal results during the excitement stage of a chloroform induction [1] and during the inhalation of gas and oxygen for a major operation. This patient recovered with hemiplegia. Patients with *intra-thoracic aneurysm* should not be given ether; nor is nitrous oxide suited to their condition, which is most suitably managed by C.E. mixture or chloroform and oxygen.

Patients suffering from **thrombosis of veins** must be treated on the same lines as those with atheroma or aneurysm—*i.e.*, every effort is to be made to avoid an excitement stage and cyanosis. Generally an open method will be found more suitable than a closed one, and the use of preliminary sedatives is valuable. Large doses of bromide during the day preceding operation are with some persons more effective than hypodermics of morphia and the like on the operation morning in securing the desired quiet induction. The danger to be specially guarded against is, of course, that of detachment of a clot during muscular excitement or a much-stimulated circulation, with consequent pulmonary embolism. It is possible, as Hewitt points out,[2] that some sudden deaths during anæsthesia are really to be put down to this accident.

Abdominal distension, whether from *ascites* or *tumour,* limits the choice of anæsthetic. The breathing in these conditions is often entirely costal, and is so restricted that anæsthesia must be obtained in the way that throws least effort on the respiratory system. Gas and oxygen, gas and ether, and all closed methods are to be avoided and air limitation permitted as little as possible. Either C.E. mixture or chloroform with oxygen succeeds best. Open ether may be substituted when the abdominal pressure is relieved. The breathing improves in vigour and amplitude when the fluid or tumour hampering the diaphragm is removed. A somewhat similar condition holds in the subjects of *acute abdominal disease* when the recti are rigid and diaphragmatic breathing restricted. It is remarkable in these patients to see the onset of abdominal respiratory movement when full anæsthesia overcomes the reflex protective contraction of the abdominal wall. Moreover, a hint as to diagnosis is sometimes

[1] *Lancet,* Nov. 12, 1910, p. 1415.
[2] Hewitt's "Anæsthetics," 1912, p. 169.

given by the contraction remaining over the affected viscus when the rest of the abdominal wall has relaxed.

Affections of the **kidney** with **albuminuria** affect the choice of anæsthetics owing to the fact that deep ether anæsthesia and long administrations of either ether or chloroform augment the albuminuria. Moreover, it is in patients suffering from albuminuria that the rare occurrence of acute pulmonary œdema is to be feared if much ether is inhaled. It would appear, then, that gas and oxygen or spinal anæsthesia are to be preferred to inhalation of ether or chloroform whenever possible for the performance of long operations on persons afflicted with albuminuria. At the same time it must be recognised that a great many operations have been safely performed under ether upon persons whose urine contained albumen at the time. Prolonged deep narcosis with ether can cause albuminuria even in persons with healthy kidneys, and the same is true of chloroform, though the result appears less readily with the latter drug. The condition is only transient. It is stated [1] that when light anæsthesia is employed with imperfect muscular relaxation albumen and casts appear in the urine more frequently than if a longer and deeper narcosis has been employed. On the other hand, very deep anæsthesia was again followed by an increase of albumen and casts. These appearances in the urine of patients who had been operated on were paralleled by rabbits subjected to experiment.

When the **liver** is diseased, or if **jaundice** is present, chloroform should be avoided whenever possible. This anæsthetic is of itself occasionally followed by jaundice, and its deleterious effect on the metabolism of the liver cells has been clearly shown in the laboratory.

When anæsthesia is necessary for a *diabetic* subject, if there is time treatment must be directed to reducing the amount of sugar in the urine before operation. Dr. Pavy [2] held that, when sugar was absent, or present only in small quantity, general anæsthesia was safe for diabetics. Often, however, it is necessary to operate for diabetic gangrene without opportunity for improving the patient's glycosuria first. All general anæsthetics are dangerous in such circumstances because of the possible supervention of diabetic coma upon the anæsthesia. Spinal anæsthesia is to be chosen when possible. Nitrous oxide and oxygen, with local anæsthetics injected into the main nerves, has provided safe anæsthesia for amputation of the thigh in diabetic subjects. Short operations, as for carbuncle, that may be required in these

[1] *American Year Book of Anæsthesia*, 1915, p. 174.
[2] Hewitt's "Anæsthetics," 1912, p. 174.

patients can generally be safely performed under nitrous oxide and oxygen. Chloroform is more likely than any other anæsthetic to lead to fatal coma in the diabetic. This is readily understood when we remember that the urine of such patients often contains acetone and diacetic or β-oxybutyric acids and that inhalation of chloroform can itself be followed by the appearance of these acids in the urine with intractable vomiting followed by coma. It has been pointed out [1] that diabetes may be shown only by blood examination making evident the existence of hyperglycæmia, when the pathological state of the kidneys is such that a considerable amount of sugar in the blood is not evident in the urine. To determine the anæsthetic risks of a diabetic, according to N. B. Foster, the blood must be examined and its combining power for CO_2 discovered. Acidosis and coma are the chief danger, and determination of acidosis is the prime requisite in deciding for or against operation. Normal blood has a combining power above 55 per cent. No patient whose blood had a combining power for CO_2 less than 30 per cent. has survived operation. This authority considers that operation is too hazardous for any patient whose blood shows combining power for CO_2 less than 35 per cent.

"With blood sugar present to more than ·35 per cent. fatality is likely even in the absence of acidosis beforehand. Anæsthesia may lead to glycosuria accompanied by more or less acidosis even in normal persons. It is a condition which aggravates and intensifies the peculiar disorder which characterises diabetes."

Anæmia renders the sufferer very susceptible to anæsthetics. Care must be taken to avoid all asphyxiation in these patients. When nitrous oxide is used unconsciousness is obtained with extraordinary rapidity, and oxygen should be freely added to the gas. Hamilton Fish [2] has pointed out the importance of blood examination beforehand in order to estimate the danger of operation in anæmic subjects. Regarding 80 per cent. or more as the normal measure of hæmoglobin, he holds that an anæsthetic cannot be safely given if this figure is reduced to 50 or lower. The amount of anæsthetic which is harmless in the presence of 80 per cent. hæmoglobin may be dangerous to life when the hæmoglobin content is reduced to 50 per cent. The experimental researches of Hamburger and Ewing,[3] which showed that chloroform produces greater reduction of hæmoglobin and greater hæmolysis than ether, agree with clinical experience in leading us to avoid chloroform when possible

[1] *Annals of Surgery*, March, 1920, p. 384.
[2] *Amer. Year Book of Anæsthesia*, 1915, p. 35.
[3] *Ibid.*, p. 38.

for patients who are suffering from grave anæmia, of whatever kind. The feebly nourished cardiac muscle of these patients undoubtedly adds to their danger.

When the **blood pressure** is unduly high ether is generally to be avoided. When the subjects of this condition undergo abdominal operations it is always advisable not to employ the Trendelenburg position.

Pregnancy has little bearing upon the choice of anæsthetics, except that it is desirable to avoid all cyanosis and violent muscular contraction. Particularly in the late months, anæsthesia accompanied by these symptoms may lead to premature delivery, and therefore in the last two months of pregnancy it is wise to avoid the administration of nitrous oxide unless this is accompanied by free dilution with oxygen. Anæsthetics have frequently been taken within a few days of delivery without the process being prematurely instigated. When *labour* is in progress women take anæsthetics with unusual felicity. It is commonly held that chloroform at this time is deprived of its danger. That doctrine has led to fatality within the writer's knowledge, and when in abnormal labour any severe or protracted operation has to be performed the usual lines of safe practice must be followed. For ordinary confinements the light degree of narcosis usually maintained with chloroform seems perfectly safe and convenient (see p. 277).

Lactation does not appear to influence the action of anæsthetics, and no departure from usual practice is necessary when administering to a woman who is suckling. Care must be taken, however, that the baby is not put to the breast too soon after the mother has been under chloroform if this anæsthetic is employed. An interval of at least six hours is advisable.

Those who *are in pain* take anæsthetics readily and with extra safety—anæsthesia is the natural antidote; this partly accounts for the unusually favourable behaviour towards anæsthetics of women in labour.

The **insane** are as amenable to narcosis as others, but there may be unusual difficulty in bringing them to submit themselves. The subjects of persecution mania and like disorders, regarding most people and their actions with suspicion, are with difficulty induced to believe that the anæsthetist, with his unwonted apparatus, is not bent on murder, or at least robbery with violence. On recovery from anæsthesia the insane are neither better nor worse than they were before. Patients, however, who are subject to recurrent attacks of insanity may suffer from an attack on recovering from anæsthesia, though they were sane beforehand.

Aged persons, though sane, often show mental disturbance for several hours or days after emerging from anæsthesia.

Epilepsy.—An attack may be started by the anæsthetic, but this has occurred only rarely, although anæsthetics have been administered to epileptics on a great many occasions. They should be selected according to the usual principles. Preliminary administration of bromide is beneficial. Dr. Hassell [1] records a case in which the patient, a child of seven years undergoing the operation for appendicitis, had several epileptic attacks during anæsthesia, at first under full chloroform narcosis and later when partly under ether.

People who are already **partly unconscious**, as from *tumours within the skull, concussion, alcoholic or other poisoning,* require but little anæsthetic, and that should be given gradually by an open method. The first effects of the anæsthetic vapour on the partially conscious subject are often to arouse him to a slight extent. Very little inhalation, however, is needed to procure full unconsciousness, and then the anæsthesia must be kept light. After the flap has been cut, for instance, in trephining, an operation often required on the semi-conscious, no further anæsthetic is generally needed till the dura mater is incised, and often not even then. When a patient is already *comatose* before operation no anæsthetic, of course, is needed at the start. Incision, however, will often arouse a person in this condition sufficiently for some anæsthetic to be required for the carrying out of the operation. Generally a very dilute chloroform vapour is the most appropriate agent to employ. It is for these head operations that chloroform instruments supplying a constant weak vapour and enabling the administrator to be away from the site of operation are particularly valuable. The Vernon Harcourt with a long tube between face-piece and chloroform bottle or Shipway's or Junker's apparatus with an extra long tube to face-piece are generally most suitable. Where **shock** is already present before operation anæsthetics must be handled with great discrimination. The rules for their selection and administration are laid down in the paragraphs dealing with that condition (p. 331).

Fever renders the patient apparently less susceptible to narcosis. The induction generally takes longer, very likely because of the shallow respiration often present. When anæsthesia is induced there is not generally the necessity for any unusual amount of anæsthetic. Acidosis is said to occur in these patients after anæsthesia with unusual frequency.

Malarial subjects do not react normally to anæsthetics. To nitrous oxide they may show a lack of susceptibility so extreme

[1] *Brit. Med. Journal,* May 1, 1920, p. 624.

that this anæsthetic may be useless for them,[1] and the stronger anæsthetics may require to be used in abnormally large amounts. An acute attack of malaria may follow upon the anæsthesia. Acute dilatation of the heart during or following operation is said to occur frequently in malarial subjects. Ether is considered to be the safest anæsthetic.[2]

Intestinal obstruction that has been present long enough to be accompanied by quiet vomiting puts the patient into peculiar danger. The vomit in this condition is a regurgitation of thin, dark fluid from the stomach, and is quietly accomplished with so little effort from the abdominal muscles that it may almost escape notice till the fluid issues from the mouth. Thus the mouth and pharynx may fill and the fluid brought up from the alimentary tract be inhaled into the air passages. To prevent this catastrophe closed apparatus is to be avoided, so that the face may easily be observed. The position of the patient is to be so arranged that it is mechanically impossible for fluid to reach the larynx from the mouth. This is achieved by tilting the head well to one side and to a lower level than the larynx and raising the opposite shoulder on a sandbag or pillow. The mouth is kept half open by a Mason's or Doyen's gag throughout the administration and the lower cheek frequently sponged clean of any fluid that may be brought up. It is noteworthy that this dark, thin fluid when examined is found to consist almost entirely of altered blood pigment, and is no doubt exuded from the lining of the stomach and intestines. It may smell fæcal, but in my experience never contains fæcal matter. Three good illustrative cases of death from asphyxia caused by inhalation of liquid vomit during operation for intestinal obstruction are to be found in the Society of Anæsthetists' records.[3] It is advisable to maintain as light a narcosis as is consistent with the surgeon's convenience for these patients, generally with open ether. The amount of fluid regurgitated when obstruction has been present for days may be enormous, so that it is easily understood that the patient may quickly be drowned by it if due precautions are not taken. Washing out the stomach is of no service, it fills up again at once ; if such washing is desired, it should be done before the anæsthetic is administered. In order to make inhalation of fluid into the air passages impossible it has been suggested that a tracheotomy should be performed or the larynx be intubated, a stomach tube being kept in the stomach throughout the operation and the pharynx packed. An apparatus designed to make vomiting impossible during these operations

[1] Hewitt, *loc. cit.*, p. 333.
[2] *Lancet*, July 26, 1919, p. 156.
[3] *Trans. Soc. Anæsthetists*, Vol. 5, p. 157.

for intestinal obstruction was described before the Society of Anæsthetists.[1] The chief features of it besides a sound were two rubber bags joined by a tube and connected to a pump. One of these bags is passed into the stomach, and when distended blocks the cardiac orifice, making the escape of vomit impossible. The inventor was said to have used the apparatus with success. The regurgitation of fluid from obstruction often happens as soon as narcosis is induced, as though the cardiac and pyloric sphincters of the stomach relaxed then and allowed the alimentary tract, unable to pass on its contents in the normal direction, to send them up into the mouth.

[1] *Trans. Soc. Anæsthetists,* Vol. 7, 1905, p. 20.

CHAPTER XVI

THE PRELIMINARY USE OF NARCOTIC AND OTHER DRUGS

THE use of sedative drugs before the administration of anæsthetics has become common of recent years. Many anæsthetists employ them in routine fashion. Some of these agents have, however, very powerful actions of their own. It sometimes happens, moreover, that the good derived from them is more than outweighed by the undesirable symptoms that they call forth. It is therefore very needful that they should be used with careful discrimination, that definite objects should be aimed at in their employment, and that, with the possible exception of atropine, they should not be used in a haphazard or routine manner. With these provisoes very great advantages may be obtained by the use of various drugs before the administration.

Firstly, let us define our aims in the use of these preliminary medications. They are—

(1) To secure a tranquil state of mind on the part of the patient, which will release him from fear or apprehension and prevent the occurrence of psychic shock ;

(2) To diminish any dangerous effects of the anæsthetic employed, as, for instance, by counteracting depressing influences upon the circulatory and respiratory centres ; and to diminish surgical shock ;

(3) To increase the desired effect of whatever anæsthetic is used so that a less amount of it becomes necessary ;

(4) To diminish any undesirable after-effects, but to prolong the period of analgesia during recovery ;

(5) To render effective some method of anæsthesia which would of itself be insufficient.

This employment of narcotics is in a sense a return to the earliest efforts at anæsthesia. The drugs used, however, are different, and they are merely adjuncts, not the main instruments, of the desired narcosis. At the same time they play in some combinations an important, if not indeed a leading, part in securing anæsthesia. This is the case, for instance, when repeated doses of scopolamine and morphia precede an operation performed under local anæsthetics. In such cases I have seen the effect

of the preliminary drugs so pronounced that it was doubtful whether any local injection at all was necessary. Again, the hypodermic injection before a short administration of nitrous oxide and oxygen often plays at least an equal part with the inhaled anæsthetic, and I have seen an operation done ostensibly under spinal analgesia in which, no cerebro-spinal fluid having escaped, it is more than doubtful whether the entire analgesia was not due to the large preliminary injections that had been given. These are exceptional instances. In estimating the value of preliminary narcotics it is useful to ask to whose aid they will come—to that of the patient, the surgeon, or the anæsthetist ? When duly selected they undoubtedly help the patient by saving him discomforts. Do they directly help the surgeon at all ? It is certain that some surgeons are very averse to the use of these drugs, and the reason I believe to be the well-founded one that they render relaxation of muscles more difficult in abdominal cases. That this is sometimes true of morphine and allied drugs I am sure from repeated experience. Moreover, the slowing effect of these drugs upon the respiration makes it very difficult to overcome any rigidity of abdominal muscles which may occur. The anæsthetist also is, then, by no means helped in such a case, although he may have derived much assistance during the induction of anæsthesia by the quiet state of a patient who would otherwise have been nervous and difficult of control. It is seen, therefore, that the advantages and disadvantages must be set against one another before sedative drugs of the morphia class are employed in abdominal cases. If the patient is of a muscular and plethoric type they may well be used, the anæsthetist recognising that he will have to give his inhalation anæsthetic in full measure afterwards, for which purpose he will probably need to employ oxygen with it. In those patients in whom the preliminary drug is required solely for its quieting action upon the mind, if an abdominal operation is to be done, the best results will be gained by avoiding morphia and relying upon the free use of bromides. These should be given in doses of 20 grains three times daily for the two days preceding the operation, the final dose being at least half a drachm on the night immediately before.

Operations upon the tongue and naso-pharynx provide a further instance in which morphia, omnopon, and the like are best avoided. In cases such as these it is not advisable to have the laryngeal reflex abolished during, or very sluggish for a long time even after, the operation. Such an anæsthesia increases the chance of inhalation of blood into the air passages, with consequent lung complications. This contra-indication does not hold good for resection of the nasal septum, as in this case blood is easily

kept away from the air passages; preliminary sedatives have been frequently used before these operations with advantage. It has been raised [1] as an objection to their use in these and in eye operations that they cause free venous dilatation which leads to inconvenient oozing. This is, however, controlled by the local constricting injections used by the surgeon. They are similarly undesirable before laryngo-fissure and other operations upon the larynx or trachea. Morphia should not be given to infants or to the very old; generally speaking, those over seventy years of age are dangerous subjects for any form of opium if they are to undergo an operation.

The combined use of narcotic drugs and inhalation anæsthetics is first recorded, as far as can be ascertained,[2] in 1861, when a patient was anæsthetized by rectal injection of belladonna following chloroform, which had failed to produce narcosis. A little later, Nussbaum, of Munich, practised the injection of morphine during chloroform anæsthesia. He described a long after-sleep without vomiting as the result of his method. At the present time it is generally held that if morphia prevents vomiting in some cases, it certainly causes it, or at any rate nausea, in others. Claude Bernard [3] in lectures upon the character and action of various anæsthetics described the effects he had produced experimentally with morphia and chloroform. He found that, if chloroform were inhaled by an animal previously narcotized by an alkaloid, only a very small dose was needed to get anæsthesia. On the other hand, injection of morphia into an animal beginning to recover from chloroform restored insensibility. This tallies with Nussbaum's experience, for, by injecting acetate of morphia into a chloroformed patient, a deep sleep of twelve hours ensued after stopping the chloroform.

The use of morphine before chloroform was deprecated by Poncet as a result of his experiences in the Franco-Prussian War (1870).[4] He believed that more severe after-vomiting followed. Regnier, again, regarded the combination as dangerous on the grounds that morphia lessened the rate of elimination of chloroform and placed the patient in danger during the recovery period. In this connection we may remember that in patients who are already the subjects of acidosis morphia reduces their power to free themselves from that state, although it lessens the chance of acidosis arising through anæsthesia in those who are free beforehand. Later observers, Dastre and then Horsley,

[1] W. J. McCardie, *Brit. Med. Journal*, 1912, Vol. 2, pp. 620 *et seq.*
[2] *Med. Times and Gazette*, Vol. 1, p. 259.
[3] *Lancet*, Vol. 2, 1869, p. 789.
[4] *Proc. Royal Soc. Med.* (Anæsthetic Section), Vol. 4, Dudley Buxton.

showed the risk involved in the use of morphia with chloroform, owing to the depressing effect of the former upon the respiratory centre. Later the practice of combining atropine with morphine appeared to destroy the validity of these objections, and the modern use of preliminary drugs is largely influenced by the knowledge that if various alkaloids are used in combination they assist each other in some ways while acting antagonistically in others.[1] Thus the narcotic effect of two alkaloids used together is held to be more than the summation of their two separate effects, and on the other hand the stimulating effect of atropine on respiration counteracts the depression of morphia. Atropine has been shown experimentally to paralyse the terminals of the vagus nerve both in the heart and in the bronchioles. It is therefore presumed to lessen the danger of reflex cardiac syncope during chloroform inhalation, and also by diminishing the tension of the muscular coat of the bronchioles to facilitate the air current in anæsthesia and lessen the risk of lung complications afterwards. It is difficult to disprove or to support these claims clinically. The evidence, however, appears to be strongly in favour of the contention that preliminary use of atropine alone is at least devoid of risk, and that it adds to the patient's safety when used before chloroform. Its most obvious effect in practice is the diminution of secretion which it causes. Under its influence the patient secretes little mucus, saliva, or sweat. This is a great help when ether is freely used. The diminished perspiration lessens the chance of shock by helping to preserve the body's heat ; the absence of mucus and saliva secures quiet breathing undisturbed by cough, and lessens the chance of after-vomiting due to swallowed secretions saturated with ether. As regards their physiological action, atropine and hyoscine may be regarded as identical.[2] Webster found in a number of experiments no evidence of action on the vaso-motor system and no rise in blood pressure. On the heart he found the chief effect to be a diminution in the extent of movement after a slight temporary augmentation of its beat. This observer draws attention to the peculiar tolerance which can be acquired for atropine, and states that, even in the course of a single experiment, a dog can be given with safety towards the close a dose which would have been fatal earlier in the sitting. He finds that there is no evidence that the doses commonly used on human beings are big enough to protect the heart by cutting out the vagi, and that there is no benefit when atropine is given to an animal whose circulation is already depressed by chloroform. In attempting to lay down general rules determining the use or

[1] *Proc. Royal Soc. Med.* (Anæsthetic Section), Vol. 4, Dudley Buxton.
[2] *Reports Brit. Assoc. Adv. Science*, 1910, pp. 628—633.

avoidance of preliminary narcotics we must take into account the method of anæsthetic administration which is to be used. Thus Flagg maintains that such drugs are dangerous in conjunction with open methods, but safe with closed, and that the re-breathing of oxygen from a bag obviates any cyanosis or respiratory defect that may arise in the course of the anæsthesia. It is certainly true that the respiratory depression due to morphia or scopolamine or both is often accompanied by cyanosis, and that with the shallow breathing which they cause this cannot be dispelled during anæsthesia except by the use of oxygen with the anæsthetic. Such cyanosis, however, is not more common with open than with closed methods after preliminary injections. When *nitrous oxide* is to be the only anæsthetic agent relied upon for a major operation a preliminary narcotic may be regarded as essential unless the operation is of the most superficial character.

Again, before *spinal and local* analgesia there is every advantage in employing sedative drugs, and the same may be said for the intravenous and rectal use of ether. Generally speaking, it may be said that drugs of the morphia type are much better associated with ether than with chloroform. With the latter there is always present the danger of a serious degree of respiratory depression from the combination. The fact that *idiosyncrasy* undoubtedly exists on the part of some individuals in their reaction to morphia has to be borne in mind. Such persons are rendered sick and faint and are even prostrated by the injection of a quarter of a grain. It is for this reason that morphia should not be used in routine fashion in hospitals before operation. Nor is it advisable ever to give so large an amount as a quarter of a grain before operation to any patient who has never had morphia before. When it is possible to test the patient's reaction to morphia by giving an injection several days beforehand that plan may be adopted. The preparation known as omnopon, which consists of a mixture of the soluble chlorides of the various alkaloids of opium, is stated not to produce the nauseating effects sometimes due to morphia, and the writer's experience bears out this claim. This drug may be used as a preliminary without the precautions necessary for morphia. At the same time it must be admitted that, if the dose of morphia does not exceed one-sixth of a grain, objectionable results from its use are extremely unusual. The length of time that elapses before operation after giving narcotic drugs is to be arranged carefully, for it is best that the preliminary drug should be producing its full effect before the anæsthetic is introduced. Otherwise the anæsthetist may be greatly hampered by the appearance of symptoms during anæsthesia which are due to the fully-developed action of the preliminary drug. One hour

beforehand is generally the proper time for the preliminary injection. When this injection is of morphia or omnopon or scopolamine or combinations of these the patient should be kept quiet in a darkened room after the injection. The fullest effect is obtained if in addition the ears are plugged with cotton-wool. After this treatment when scopolamine has been used, alone or with the other drugs mentioned, the patient is often so drowsy that he can then be rendered unconscious without the slightest mental disturbance. Indeed, if the induction is carried out with the patient still in bed, he can be transferred to the operating table, operated upon, and returned to bed without his memory retaining anything on return of consciousness beyond the initial hypodermic injection of scopolamine. Even without this complete obliteration of subsequent events the single injection commonly produces a tranquillity of mind which saves the patient from any of the evil effects of fear. To get the full amnesic results repeated injections are generally necessary, as described in the pages dealing with "twilight sleep." Scopolamine is capable in some persons of producing excitement and even delirium instead of the desired sleepiness. I have never seen such an effect when the drug has been combined with omnopon or morphia.

In addition to the drowsiness during induction the most notable symptoms present during anæsthesia after the use of morphia and allied drugs are the altered character of the breathing, the smallness of the pupil, and the sluggishness of reflex response. The breathing is commonly both slower and shallower than it is in ordinary anæsthesia. This poor quality of respiration is often accompanied by some cyanosis that cannot be counteracted without the use of oxygen, and this should always be at hand when preliminary narcotics have been used. The pupil is generally firmly contracted even when scopolamine or atropine has been used with morphia. The usual doses of morphia do affect the pupil, but the usual dose of atropine does not. Commonly when the latter drug has been used alone the reactions of the pupil are the same as when no preliminary drug has been introduced. Reflex movements are evoked with greater difficulty when morphia has been used, and thus a quiet condition of the patient can be maintained although the narcosis is of a light degree only. In such a state the corneal reflex may remain unusually brisk, as I have often observed. The doses of the respective drugs to be used in the case of adults are :

Morphia, gr. $\frac{1}{6}$;
Omnopon, gr. $\frac{1}{3}$;
Scopolamine, gr. $\frac{1}{150}$;
Atropine, gr. $\frac{1}{100}$.

One injection of omnopon, scopolamine, and atropine together in the above amounts commonly produces a tranquil state. Other sedative drugs that have been employed before anæsthetics are chloral hydrate, chloretone in doses of 5 grains, and heroin. Cocaine (2 per cent. in adrenalin 1 to 10,000) has been used as a throat spray with the object of abolishing the risk of laryngeal reflex syncope.[1]

When any of the sedative drugs above mentioned are given it is desirable that the patient should not be allowed to walk from his bed to the operating table. He must remain passive after the hypodermic injection, and when moved should be allowed to remain recumbent. We may sum up the above considerations with regard to preliminary drugs by saying that—

(1) They may be employed with advantage in the case of highly-nervous and apprehensive individuals; also in the case of the alcoholic and physically powerful.

(2) They should be avoided in cases of operation which involve the access of blood to the air passages, in all cases of respiratory difficulty from any cause, in all cases of any degree of drowsiness and of advanced renal disease.

(3) They are not to be used for the very young or very old.

(4) These considerations do not apply to atropine, which may be used in routine fashion.

(5) The symptoms of anæsthesia are altered after preliminary narcotics, and they should therefore be used only by those who are acquainted with their effects.

[1] *Therapeutic Gazette*, 1903, Vol. 19, p. 308.

CHAPTER XVII

THE POSTURE OF THE PATIENT AND ITS BEARING ON ANÆSTHESIA

In preceding pages the position of the patient during operation has been mentioned more than once, but, as this plays so important a part in the conduct of anæsthesia, it deserves fuller consideration. We have described the routine position for all ordinary operations —viz., the patient on the back with the head slightly raised and turned to one side. Many of the troubles which beset the student giving his first anæsthetics are seen to depend on want of attention to detail as regards this position. Sometimes the pillow is below the shoulders and props up too much the upper part of the chest. Sometimes the head is in the middle line and easily leads to obstruction by a dropping lower jaw, or the breathing is obstructed by a head that is too flexed. Coughing and swallowing may be made impossible by one that is over-extended. The first thing to be secured in any position that has to be adopted is a free air-way and unembarrassed respiratory movement. With some positions we shall see that these essentials are not easily maintained. Position has to be altered sometimes in the course of operation. It behoves the anæsthetist on those occasions to be sure that anæsthesia is deep before the move is made and that he takes charge of the head while the patient is moved, so that he can prevent any local obstruction arising from want of attention to the lower jaw. If anæsthesia is insufficient while the patient is turned into the required position, retching or coughing or vomiting may easily be started. Shock also is sometimes brought on by an alteration in the position of the trunk. When the alteration is into a position in which the head is raised above where it was before, as, for example, when after an eye or a breast operation the head or all the upper part of the body is raised for the application of bandages, the depth of anæsthesia becomes of great import. Under these circumstances anæsthesia must not be so deep that the blood pressure is considerably lowered, for if this takes place sudden cerebral anæmia may follow the raising of the head (p. 59). This consideration affects chiefly patients who are under chloroform, and they must not be sat up unless the corneal reflex is brisk. The changes effected during operation are mostly to a

side or to the lithotomy position, and do not affect the upper part of the body or head.

Besides the usual dorsal position with head to one side the commonly used positions are :—

(1) The lateral.
(2) The sitting.
(3) The prone.
(4) Trendelenburg's position.
(5) Dorsal with head extended.
(6) The lithotomy position.

In the **lateral position** the patient lies on one side with the knees slightly bent. It is the position in which most people

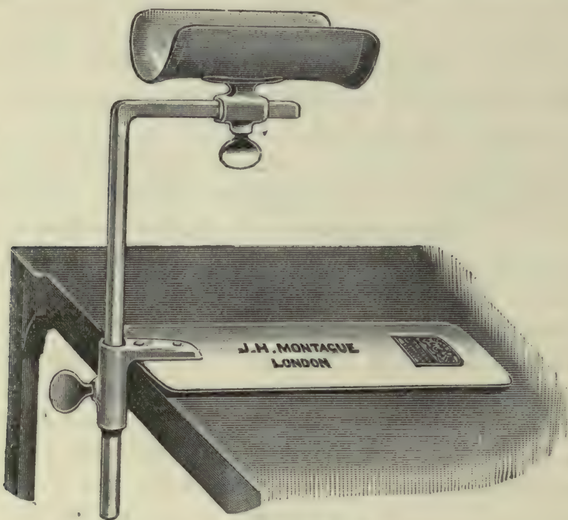


FIG. 42.

commonly sleep, and is an excellent position for anæsthesia during all operations that can be performed in its presence. Many surgeons employ it for tonsil and adenoid, antrum, and other operations about the face and throat, and it is admirable from the anæsthetist's point of view, blood falling into the lower cheek and being easily got rid of without risk of inhalation. The lateral position with the head fully extended is admirable for bronchoscopy, œsophagoscopy and the like. When the patient is rolled rather further over on to his face, as for many renal operations, the position is sometimes called the latero- or semi-prone. The upper arm is then supported by a rest, and the under-arm must be drawn forwards and placed so as not to receive undue compression between the body and the table. With fat, short-necked persons there is sometimes difficulty in

FIG. 41A.—The usual dorsal posture

FIG. 41B.—The lateral position.

FIG. 41C.—Head over-extended (for tonsil dissection).

FIG. 41D.—Mild form of Trendelenburg's position

keeping the face out of the pillow enough to allow of the application of the anæsthetist's mask. It may then be necessary to have the upper shoulder held a little back. The support of the upper arm on Carter Braine's or similar rest keeps the thoracic movements free (Fig. 42). When this position is to be adopted anæsthesia is first induced in the ordinary dorsal, or, with heavy persons, better in the lateral position, and the arm rest inserted and the further rolling over achieved when full narcosis is present. In the course of long operations on these subjects in this position some embarrassment of the breathing leading to cyanosis may arise. Since it is generally inconvenient for the surgeon to alter the position at all, oxygen should be allowed to flow in gently beneath the mask, and in this way a perfectly good condition can be maintained. When the position is used for operations on the kidney it is common to have beneath the lower loin a stout sand-bag or distended, bolster-shaped air-cushion. The latter is preferable, as it can be deflated without moving the patient when the surgeon begins to close his wound.

The **sitting position** is employed in two different forms. First, that which is commonly used in dentistry, when the patient sits upright in a chair with the legs resting on the ground at each side or lightly extended before him. This position is, as has been said, used by some operators on the nose and throat. Some authorities believe that when it is in use chloroform should not be given at all unless preceded by ether. This is a safe rule to guide those without a wide experience of chloroform. The latter often find it expedient to use chloroform from first to last for the operations of those surgeons who work on the nose with the patient in the sitting position. Great care is taken over the depth of anæsthesia when full narcosis is present, but in the early stages the ease with which swallowing or coughing is effected makes the induction devoid of difficulty. A rolled towel is often needed behind the neck to preserve the correct position of the head during anæsthesia. The tendency of the patient when completely relaxed to slip down in the chair is an awkward feature of this position, which is not one of choice for the anæsthetist except in dental operations. It has been employed during the operation for removal of the Gasserian ganglion, when it helps to keep the operation site free from congestion. The *second variety of the sitting position* is that in which the patient is propped up on the operating table. Here the lower limbs are horizontal, but the upper part of the body is nearly at a right angle with the table. It is the position chosen by many operators on the nose and throat, who prefer it to the lateral position, because the parts are in the position in which they are customarily inspected. For an anæsthetist it is less

desirable, and he must either preserve a coughing reflex or see that blood is prevented from entering the air passages by a post-nasal sponge or by frequent mopping. This position, or something nearly approaching it, has sometimes to be adopted on account of the respiratory difficulties of the patient. Whenever from abdominal distension or from intra-thoracic trouble the patient breathes more easily when sitting than when lying, he must be allowed to inhale the anæsthetic in the position of greatest ease. When anæsthesia has been induced the position is gradually changed, if necessary, for the performance of the operation. It has often appeared to the writer that patients take longer to become unconscious when inhaling the anæsthetic in a sitting position.

The *prone position*, which is needed for operations on the spine, for some on the head, and by some operators for operations on the kidney, is perhaps the most awkward of all for the anæsthetist. The difficulty of reaching the face described in connection with the lateral position is exaggerated unless the table has a special device for overcoming it. In Cushing's apparatus the shoulders are lifted a few inches off the table, and a head-piece separated from the rest of the table supports the face. In the absence of any arrangement of this kind the anæsthetist will sometimes find it necessary to allow the head to project beyond the edge of the table. The use of intra-tracheal ether, advocated by Percy Sargent [1] for operations on spinal tumours, certainly overcomes the defects of the prone position. Once the catheter has been introduced the position of the patient makes no difference, and the respiratory embarrassment that may follow on the prone position long maintained is entirely overcome by the mechanical distension of the lungs. The *prone position for kidney operations* is modified by arching the loins so as to give the widest separation between the lower ribs and the ilium. The head and chest are lowered, the centre part of the table is raised, and the lower limbs fall below the level of the buttocks. In this way an excellent exposure of the kidney is facilitated. The anæsthetist will often need to have one shoulder slightly supported to allow sufficient thoracic excursion and contact with the face. The position gives much of the advantage of the Trendelenburg.

The *Trendelenburg position* is not, as a rule, used during induction, but when anæsthesia has been established the table is tilted till the head is the lowest part of the patient. The shoulders rest against supports and the legs are flexed and bandaged over the lower flaps of the table, which are let down. The degree of tilting of the table may be extreme, till the patient is almost

[1] *Brit. Med. Journal*, Jan. 10, 1920, p. 37.

vertical from the pelvis to the head, or quite slight, in accordance with the operator's wish. The head-down position is a great aid in the avoidance of shock during operation. It permits the use, if wanted, of prolonged deep chloroform narcosis with a safety that is hard to achieve otherwise. In corpulent persons there may be respiratory difficulty, and it is often necessary, particularly with the edentulous, to use an artificial air-way throughout. The venous congestion brought about by the position aggravates any tendency to mechanical obstruction in the upper air passages. Oxygen is often needed for the avoidance of cyanosis. When the operation is finished the patient must not be brought too rapidly to the horizontal plane. The objections brought against the Trendelenburg position, that œdema of face and head may arise during operation and lung troubles after, are mainly based upon results which were due to permitting long-continued imperfect aeration of the blood while the position was maintained.

The *dorsal position with the head extended* is that which has been described in connection with the dissection of tonsils during deep ether narcosis (p. 264). Some operators prefer this position to all others while operating for cleft palate, the child's head then being allowed to hang over the end of the table. The position renders the entry of blood into the larynx impossible, but it is not one in which breathing is facilitated. Those who do not like a lateral position often use the dorsal position with the shoulders raised and the neck fully extended for bronchoscopy and similar procedures.

In the *lithotomy position* the patient is on the back, with the thighs flexed on the pelvis, the head turned to one side, and the legs flexed on the thighs. This is best brought about by the use of uprights fixed to the table, these providing broad rests over which the legs are flexed, or else ankle pieces to which the feet are fastened. Clover's crutch is another means of securing the position, and can be used when the position is needed for a patient operated on in bed. The strap of the crutch is passed behind the neck, over one shoulder, and under the other. In using the lithotomy position care is necessary that there is no undue pressure behind the knees, if the legs are flexed over rests, and that the strip does not cut into the thighs or press too hardly on the neck when Clover's crutch is used. Very fat people do not breathe easily in an extreme lithotomy position. Hewitt[1] refers to a case of gangrene of the legs following the use of this posture.

[1] "Anæsthetics," 1912, p. 245.

CHAPTER XVIII

UNDESIRABLE CONDITIONS OF THE PATIENT DURING ANÆSTHESIA: THEIR CAUSATION AND TREATMENT

Respiratory Obstruction—Artificial Respiration—Shock—Resuscitation Methods

The minor troubles which may interfere with the smooth conduct of anæsthesia have been mostly described. We have seen that in the early stages swallowing, coughing, retching, or vomiting may be due to insufficient anæsthetic, and that the spasm which accompanies light stages of narcosis may interfere with breathing. This spasm subsides with full anæsthesia, and its treatment we have seen to be the provision of a free air-way, the stimulation of breathing, and the free application of the anæsthetic. The more serious conditions which may need treatment now demand consideration. The causation of these conditions, which are important because they involve failure or threatened failure either of respiration or of circulation, is often complex. It may be due mainly to the anæsthetic, or on the other hand this may play a part insignificant compared with the effect of the operation or the position of the patient. Thus surgical shock at the end of a long, severe operation may bring the patient to a state of circulatory feebleness in which the anæsthetic plays no part, or hæmorrhage alone, if profuse enough, may equally reduce him. The wrong position, again, during an operation for empyema may jeopardize or lose the patient's life, as we have seen (p. 269). On the other hand, the anæsthetic itself, if given to excess, may lead to a state almost indistinguishable from that brought about by surgical shock. The treatment and causation of shock we must consider later.

Another cause of serious symptoms is to be found in what may be called the accidents of anæsthesia. Under this term we include the inhalation of foreign bodies and the faintness which may accompany the vomiting of recovery. The undesirable conditions which we ought to consider now are all due to causes which affect primarily either the breathing or the circulation The breathing may be seriously interfered with :

By Mechanical Obstruction.—This may be due to spasm or

swelling either within or above the larynx. In its most common form it is due to congested tongue and fauces associated with spasmodic retraction of the tongue. We have seen that usually this is only a minor difficulty, but in exceptional persons, usually with fat chins and thick necks, the swelling of tongue, fauces, and of the laryngeal folds may be so intense and persistent that only a laryngotomy or tracheotomy renders breathing possible. Even after this the spasmodic rigidity of the chest may prevent air entering until it is actually blown into the lungs through a catheter. Before using this last resource of opening the air passages by operation the anæsthetist must be sure that, with the mouth opened and the tongue drawn forward, it is impossible to get air to enter the chest. The occasions on which he has to fall back on laryngotomy or tracheotomy because of spasm and swelling are fortunately so rare that to some they never arrive at all. Hewitt [1] relates a striking example in which the tongue, soft palate, fauces, and adjacent parts were so enormously swollen that it was practically impossible to pass a finger to the epiglottis. It is noticeable that in this case the extreme trouble arose after the beginning of the operation had been accompanied by slight reflex movement. It is highly probable that reflex spasm played a part in bringing about the respiratory arrest in addition to the swelling. For the respiration may be seriously interrupted by *reflex action* during an operation, and is more liable to be interfered with in this way if the narcosis is light.

The following was a good example of reflex respiratory stoppage. A man of 25, an athlete with good teeth and poor nasal air-way, was to have the appendix removed. With a prop between the front teeth "gas and ether" was well taken. The abdomen was opened with no reflex movement. Corneal reflex present. Chloroform substituted for ether. About three minutes later the cæcum was pulled out of the abdomen rather forcibly. The breathing immediately stopped in the inspiratory phase. Colour, pupil, and pulse normal. Thinking that the purely reflex effect would quickly pass and breathing be resumed, I took no steps. After about one minute, no breath being drawn, lips and face were rubbed and jaw pushed forcibly forward. Still no respiration. Four compressions made of the chest, head lowered, and tongue drawn forward and pharynx swabbed with a sponge. No breath drawn. The colour was now pale and beginning to be bluish, the pupils still of small size, but the corneal reflex gone. Artificial respiration (Silvester's method) for about six movements. Spontaneous breathing then began, infrequent deep breaths being drawn. After about three minutes the respiration was normal, the colour pink, and the rest of the operation was performed under chloroform with no unusual incident.

A common cause of reflex stoppage of the breathing is stretching of the rectal sphincter, but the breathing is quickly resumed

[1] "Anæsthetics," 1912, p. 562.

unless there is present also much swelling of the upper air passages. If in the plethoric type of patient the sphincter is stretched while narcosis is light, the reflex effect, added to the congestion and spasm still present about the fauces, may cause a prolonged interval of apnœa. The mouth must be opened, the tongue drawn forward, and a sponge rapidly passed over the pharynx. If breathing is not at once resumed the chest must be compressed and, if this fails, Silvester's artificial respiration performed. The most dangerous form of mechanically obstructed breathing is met with in persons whose lower jaws, by reason of local disease, cannot be brought forward. When in addition there is an inability to open the mouth except to very small extent the administration of any anæsthetic is liable to lead to the necessity for a laryngotomy or tracheotomy. The reason for this is that breathing, becoming arrested by congestion, or reflex spasm, or both, cannot be remedied by properly bringing forward the jaw, and the opening of the mouth may not be wide enough to allow a finger to hook forward the epiglottis. Under these circumstances the air passages must be incised to allow respiration to start again.[1] The spasm which may accompany the early stages of chloroform narcosis, particularly in muscular individuals, may become dangerous. The local obstruction may become merely part of a general spasmodic condition of all the respiratory muscles, and, with breathing temporarily stopped and chloroform confined within the circulation, the strain on the right heart, dilated from the inactivity of the lungs, may, in combination with the toxic effect of the drug on the cardiac muscle, bring about fatal syncope. This is a likely explanation, whether fibrillation occurs or not, of some early deaths from chloroform inhalation by healthy subjects. It is because of the possibility of this disaster that the spasmodic holding of the breath during chloroform induction must at once be treated by stimulating the breathing, through rubbing the face and lips and by withholding the drug till respiration is fully resumed. These simple measures, if they fail, are supplemented by compression of the chest and artificial respiration.

Obstructed breathing may arise through the swelling under the anæsthetic of an unsuspected tumour in the neighbourhood of the trachea, or of an obvious goitre or glandular mass. The immediate performance of the operation is the remedy in these cases (see p. 267).

Cellulitis of the neck provides another class of patient in whom local engorgement may cause complete obstruction of the breathing. Œdema of the larynx is often present with this

[1] Hewitt, *loc. cit.*, pp. 564, 565.

condition, and the increased swelling caused by anæsthesia may lead to asphyxia either by closing the aperture of the glottis or by its occlusion from above by the congested tongue, palate, and fauces. The measures to prevent this accident are told on p. 287. If owing to their neglect asphyxia is brought about, an immediate laryngotomy or tracheotomy, which may be extremely difficult to perform, offers the only chance of saving the patient.

Angioneurotic œdema is a condition which may cause sudden œdema for no apparent reason. This œdema may affect the larynx during anæsthesia and obstruct the entry of air, so that an immediate tracheotomy is required to prevent asphyxia. When a patient is known to be liable to angioneurotic œdema, the anæsthetist must be prepared for this contingency. Fortunately the affection is not a common one. Buxton [1] mentions two instances in which it interfered with anæsthesia.

Mechanical obstruction due to the **inhalation of blood, of portions of growth, of pus or mucus and saliva,** may occur during operations about the face and throat. The measures necessary for the prevention of these accidents have been detailed. Prevention is all-important, for treatment can do little if the offending material has passed the larynx. Inversion must be tried, and followed, if necessary, by tracheotomy and removal of the inhaled matter by aspiration or suction through a catheter.

Rupture of a gumma [2] with fatal inspiration into the lungs during anæsthesia is described by McCardie. The anæsthetic, chloroform, had been taken without any unusual symptom arising, but before operation began it was noticed that, with small pupils and lively reflexes, the face was becoming blue and the breathing embarrassed. It ceased altogether, and, in spite of artificial respiration and tracheotomy with insufflation of oxygen, was not resumed. *Post mortem,* a broken-down gumma was found in and around the bifurcation of the trachea. Much muco-pus blocked all the main bronchi. For an accident like this there appears to be no helpful treatment.

Blood may enter the respiratory tract owing to hæmoptysis or epistaxis, but these are extremely rare causes compared with operation in the neighbourhood of the air passages. During the latter it is quite common for small quantities of blood to enter the larynx and to be expelled at once or after operation, no harm being done. Fairly large quantities of blood can be accommodated in the pharynx or in the dependent cheek and remain there harmlessly during operation when the position of the head renders this possible. When, however, blood cannot rest in these places

[1] "Anæsthetics," 1920, p. 414.

[2] *Proc. Roy. Soc. Med.* (Anæsthetic Section), Vol. 4, 1911, p. 26.

nor flow from the mouth, owing to the position adopted, then it must be frequently sponged away or else the coughing reflex retained throughout the operation. If blood is inhaled into the trachea its presence will generally be shown by a loud, moist râle heard during expiration. On the appearance of this the patient should be allowed to cough. If the coughing reflex does not readily return when the anæsthetic is withheld, cold water should be poured on the face.

Mucus in excessive quantity may cause actual respiratory obstruction by occluding a portion of the air passages, or it may set up laryngeal spasm. Moreover, it may during comparatively light narcosis cause such frequent swallowing movements that breathing cannot be properly carried on. Florid-faced children and those with adenoids, if given closed ether, are most likely to suffer in this way. This source of interference with breathing is much less commonly seen now than when closed ether administration without the preliminary use of atropine was the vogue. With the use of open methods and preliminary alkaloids mucus is a negligible source of respiratory obstruction. Exceptional persons, however, may secrete mucus to an undesirable extent during ether inhalation even with an open method. Moist inspiratory and expiratory sounds showing the mucus to be present in the trachea should lead the anæsthetist to abandon ether for these people. Chloroform can be safely substituted after a cough has cleared the air passages.

Two more kinds of **foreign body** need special mention as dangerous entrants to the air passages during operation—vomited matters and extracted teeth.

Firstly, **vomited matter,** whether solid or liquid, has been responsible for many fatalities during anæsthesia. The proper preparation of patients and competent handling during anæsthesia should entirely prevent the inhalation of vomited matter if vomiting happens at all on the operating table. Such preparation, however, is not always possible. Urgent surgery often precludes it. The subject of an emergency operation is therefore often in an unfavourable state from the anæsthetist's point of view, and a loaded stomach may lead to vomiting during operation, however skilful the administration. When this accident is anticipated the head will be kept to one side with a sand-bag behind the opposite shoulder, the mouth will be open, and the face free from any closed apparatus.

The subjects of *intestinal obstruction of long standing* are those most likely to be put into danger, by passing into the mouth large amounts of thin, liquid vomit. When solid portions of food are vomited and a piece is drawn back into the air-way

the first step to be taken is to pass the finger into the mouth and try to hook out the foreign body. The mouth must be kept open with a Mason's gag and the patient tilted to one side. If the breathing continues to be obstructed and the body cannot be removed with the finger, several compressions of the chest should be made. A cough may now dislodge the obstruction and breathing be resumed. If this does not happen and cyanosis increases, the breathing being still in abeyance, the cricothyroid membrane must be incised and a tube inserted or the opening held open while artificial respiration by Silvester's method is performed until spontaneous breathing returns. The foreign body can then be removed at leisure.

During the *extraction of teeth* a tooth, or a portion of one, or a stopping may fly from the operator's forceps and reach the back of the mouth. From here it may be drawn into the larynx by the unconscious patient. The accident is most likely during the extraction of upper bicuspids or small upper roots. The back

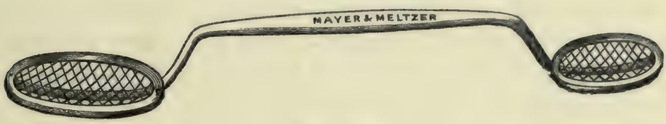


FIG. 43.

of the mouth may be guarded by Carter's spoon (Fig. 43) held in place by the anæsthetist, or by a coarse sponge pushed on the back of the tongue, or by a corner of a towel at the back of the mouth. To avoid the chance of a tooth or fragment being left in the mouth and possibly inhaled every tooth or piece extracted should be seen to be out of the mouth before the next extraction is made. If a foreign body remains on the back of the tongue it must be removed by the finger, and the jaw must not be pushed forward, as this opens the larynx. If a tooth or other foreign body enters the larynx it may at once set up spasmodic coughing and be expelled. On the other hand, stridor and cyanosis may arise and be followed by stoppage of the breathing. Directly the symptoms begin, and it is obvious that the body has not been expelled, the patient should be bent forward and his back slapped. If the symptoms persist, he should be inverted, by tilting the chair back towards the floor. If the obstruction to breathing remains serious or the respiration actually stops, a laryngotomy must be done at once. More often it happens that if the small foreign body is not expelled the acute symptoms subside. There is then great risk of a septic pneumonia or bronchiectasis or abscess of the lung being caused if an inhaled tooth or portion of

one is present in the lower air passages. The patient is to be advised to see a laryngologist and undergo bronchoscopy. Inhaled foreign bodies have, however, been coughed up as long as three weeks after their accidental entry into the larynx. When a small foreign body enters the pharynx it is, of course, often swallowed. In order that this should be possible the head must be in its natural relation to the chest and not thrown back during tooth extraction. Although during the extraction of teeth it is primarily the operator's business to see that nothing is left loose in the mouth, yet in the hurry of operation he may easily overlook the accidental leaving of a fragment in the mouth or attached to his forceps. The anæsthetist is then well advised to call the operator's attention to the foreign body which has escaped his notice, that it may be at once removed.

A variety of bodies have been recorded as entering the larynx during anæsthesia and requiring prompt treatment. Tooth plates, plugs of tobacco, the broken blade of a tooth-forceps, mouth-props and corks, a sponge, and portions of instruments used in laryngeal or pharyngeal operations have all been the cause of acute asphyxial trouble. The necessary treatment has been sufficiently indicated in the description of that proper for loose teeth in the pharynx or air passages.

In the operation for *retro-pharyngeal abscess* there is particular risk of pus invading the respiratory tract. Some anæsthetists have even urged that when an infant, as often occurs, is the subject of this affection the abscess should be opened without anæsthesia. When an anæsthetic is given for the operation the head must be so dependent that the larynx is on a higher level than the abscess. With this position and a light narcosis obtained by open method the operation can be safely conducted.

The inhalation of blood *after* operations which cause hæmorrhage near the air passages has caused fatalities the true origin of which has not always been recognized. In one instance known to the writer a child died within a few minutes of the removal of tonsils and adenoids. The death was attributed to shock after the operation and anæsthetic. *Post-mortem* examination revealed a complete blood cast of the trachea and main bronchi. Oozing blood had been quietly inhaled after the operation and the child asphyxiated before anæsthesia had passed off. Such accidents are avoided by making sure before the patient leaves the operating table that no bleeding is taking place and that narcosis has reached a light stage. The reason for the latter precaution is that if narcosis is still deep, bleeding may be in abeyance, but may start again as narcosis lightens and the circulatory force increases.

The presence of foreign matter within the air tract may alter the character of the breathing during operation without producing obstructive asphyxia. This happens when it is present in no great amount and below the larynx. Post-operative pneumonia, generally fatal, follows this accident as it does the inspiration of blood or pus.

In the following case the presence of material in the trachea was surmised during operation from the peculiar character of the breathing. There had been no previous reason to suspect it. A man of fifty was subjected to a gastrostomy on account of malignant disease of the œsophagus. He was alcoholic, with a dusky, plethoric face and "bottle-nose." No physical sign or symptom of disease within the chest. C.E. mixture followed by chloroform led to good anæsthesia after the prolonged spasmodic excitement stage anticipated from his appearance. During the operation on several occasions the breathing appeared to have stopped in expiration—*i.e.*, there would be such a long expiration that it appeared as though inspiration were not to follow. There was never, however, any actual arrest, and no chest compression was needed. I attributed this long expiratory phase to a kind of attempt at cough in a man during deep narcosis, and said that most likely there was something in the trachea. Several times also there occurred such forcible spasmodic breathing that a draughty noise was made in the abdomen by the contraction of the diaphragm, and the rush of air could be felt by the surgeon, so that at first he thought some perforation of a viscus must have occurred. There was, however, nothing of the kind, and the operation was satisfactorily completed. During the days following a solidifying pneumonia killed the patient. This was held to be an aspiration pneumonia, and on *post mortem* examination it was found that the trachea was invaded by the malignant growth, tiny portions of which had been inhaled.

A somewhat similar form of breathing to that just related, with forced expiratory straining of the recti muscles of the abdomen even during deep narcosis, is sometimes met with in the subjects of asthma.

Mechanically obstructed breathing is caused by several different **faulty positions.** It is not infrequently met when the head is thrown back to facilitate an operation on the front of the neck. For instance, when some malignant glands below the chin and an epithelioma of the lip were being removed from a stout man of sixty the neck was over-extended by a sand-bag beneath the shoulders. Although the jaw was kept forward and the tongue held out by a ligature, the colour was bluish and the breathing accompanied by stridor throughout the operation. This lasted nearly two hours, and for the last three-quarters of an hour oxygen was given with chloroform. Probably rectal ether with very little chloroform by the mouth would have been the best treatment for this patient. The obstructive stridor ceased when the head was put in its normal relation to the chest at the end of operation.

The Trendelenburg position often causes seriously obstructed breathing by the congestion and altered position of tongue and soft palate, but this can generally be perfectly remedied by the use of an artificial air-way.

Very stout persons in the lithotomy position may be so hampered in their respiratory movements as to necessitate lowering of the thighs.

When obstructed breathing is due to collapse of the arytæno-glottidean folds or to spasm of the glottic muscles stridor is present which is not got rid of by any manipulation of the lower jaw. In the case of spasm this may be due to mucus, and the first step is to clear the pharynx thoroughly. If stridor persists and causes increasing cyanosis, tongue traction must be tried. Lord Lister held that pulling on the tongue caused reflex opening of the glottis. This form of obstructed breathing is only met with during chloroform anæsthesia, and can often be abolished by substituting a deep, open ether narcosis.

Mechanical difficulty in properly expanding the lungs is met with when tight clothing is allowed to remain fastened on the patient. This cause of hampered breathing acts sometimes during dental operations when corsets on women or a tight waistcoat or belt on a man are the offending articles. The remedy is obvious.

Proper expansion of the lungs may be prevented by *distension of the abdomen* from advanced ascites or very large ovarian cyst. Generally under those circumstances anæsthesia must be induced with the patient propped up almost to a sitting position, and narcosis must be kept comparatively light till the diaphragm can work freely. The same rules apply when intra-thoracic disease interferes with complete respiration. In that case, if one lung is unaffected every means must be adopted to give the healthy side of the chest as great freedom of movement as possible.

Finally, in the prone position breathing becomes seriously embarrassed in some patients. If intra-tracheal insufflation of ether cannot be employed the patient must be tilted on to one side so far as is necessary to allow safe respiration.

Depression of the Breathing without Obstruction

Apart from mechanical obstruction the breathing may become seriously depressed or actually cease during anæsthesia from *over-dose.* When nitrous oxide is the agent, asphyxia produced in this way is preceded by obstructive symptoms, and is so obvious that treatment will at once suggest itself. Spasm,

cyanosis, and convulsive movements will lead the anæsthetist to withdraw his gas, open the mouth, and draw the tongue forward. If air does not quickly enter the lungs the chest is to be compressed, when recovery rapidly ensues. In the presence of a poorly acting heart, however, asphyxial spasm from nitrous oxide may be fatal. In exceptional cases asphyxial arrest of breathing during nitrous oxide inhalation comes on quietly. Feebleness of the respiratory movements combined with pallor of the face and bluish lips and ears are the warning. The anæsthetic must be withdrawn, face and lips briskly rubbed and the head lowered.

Respiratory arrest from too much anæsthetic may occur with ether or with chloroform. It is unusual with the former, but not uncommon with the latter drug. Before the respiratory centre is paralysed and breathing seriously depressed or stopped by ether the anæsthetist has plenty of warning. The patient will show increasing cyanosis, sweating, and exaggerated respiratory efforts which gradually cease or give way to infrequent convulsive gasps. At the same time the pupils will dilate widely and fail to react to light, and the upper lids may be partly opened, showing the sclerotics of the eyeballs, which roll back. The corneal reflex disappears. The surface of the body is cool, and the cyanosis gives way to ashen pallor if remedies do not revive the patient. The pulse becomes slow and irregular. The method by which ether is given will to some extent determine the symptoms which herald respiratory arrest. The above description of the altered breathing applies more to the closed than the open methods, in which over-dose comes on more gradually with consistently weakening respiratory movements and pallor rather than cyanosis of the face. The picture presented by respiratory failure under open ether is, in fact, more akin to that seen when over-dose with chloroform is the cause. Here gradually or sometimes rapidly increasing pallor, feeble or sometimes suddenly arrested breathing, and dilated pupils without light reaction are the usual symptoms. The treatment, whatever drug is causing these symptoms, must be promptly adopted. If the breathing has not ceased the mild measures of stimulating it by lip rubbing and by compressing the chest with expirations are first tried. If breathing stops the head is at once to be lowered, since cerebral anæmia may be combining with toxic affection of the respiratory centre to put an end to the respiration. Taking care that the air-way is free, by keeping the mouth open and the tongue held forward, the anæsthetist then compresses the chest twice. No spontaneous breath being drawn, he then performs artificial respiration by Silvester's method. It is obvious that he cannot do this and

also see after the tongue. If no assistant or nurse is at hand to hold this forward the best plan is to seize the tongue with Bellamy Gardner's tongue-clip after drawing it forward with tongue-forceps, and hang through the loop of the clip some heavy instrument, such as a Mason's gag (see p. 101). These measures, **lowering the head and applying efficient artificial respiration with the air-way cleared and the tongue drawn forward, are more effective than any remedial drugs.** Moreover, they can be more speedily applied, and therefore they are always to be relied on in the first instance. If additional help is at hand oxygen may be allowed to play into the mouth during the performance of the artificial respiration. Pure respiratory arrest from over-dose is almost always recovered from by the above measures, even if the breathing has absolutely ceased. It may be said, indeed, that if a pulse can be felt at the wrist when the breathing ceases recovery is certain. The danger is extreme when, as occurs not infrequently with chloroform, the toxic paralysis of the respiratory centre is accompanied by extremely low blood pressure and insufficient supply of blood to the brain. The treatment here is the same as that just recommended, but in addition the abdomen should be compressed and the legs raised if there is somebody to do this while the anæsthetist carries on the artificial respiration. Perflation of the lungs, which can be carried out by passing a tube into one nostril to the top of the larynx and using a foot-bellows, has revived a patient considered hopeless until this was done. Similarly if an intra-tracheal insufflation apparatus is at hand a very effective means of restoring respiration can be applied by passing the catheter and perflating the lungs with air or with oxygen.

The different means of performing **artificial respiration** must be briefly described. That most usually applicable is Silvester's. Silvester, whose name is commonly misspelt, was a London practitioner who died in 1908. He devised his method of artificial respiration for the treatment of the drowned and the still-born as well as for those in whom breathing ceased during chloroform inhalation. The patient lies on the back with the head lower than the chest, but not hanging over the end of the table. The mouth should not be widely open or the tongue dragged too far forward. If a Doyen's gag is at hand this is generally the best instrument with which to keep the mouth opened. It is left in position opened to about half its full extent. The anæsthetist, standing behind the patient's head, seizes his arms above the elbows and presses them firmly against the chest so as to expel the lung contents. If an assistant is available he should at the

same time exert some pressure on the abdomen to prevent the diaphragm from being forced down. Next the arms are drawn away from the sides and upwards beyond the head. The chest is in this way fully expanded and inspiration effected. A pause is made to allow air to enter the lungs, and then the arms are brought down and the first expiratory manœuvre again executed. The two movements are not to be hurried, being carried out about twelve times a minute.

When fluid has entered the lungs *Marshall Hall's* method is better than Silvester's, but clinically it cannot always be applied. The patient is placed on his face and pressure is made on the back to produce expiration and empty the lungs. The trunk is then rolled on its side, when, the weight being taken off the chest, the ribs rise and the lungs expand with inspiration. Care is to be taken in pressing on the chest not to exert too much force. Ribs are easily broken in some subjects, and the writer has seen a large number thus fractured both after Silvester's and after Marshall Hall's methods had been too vigorously applied.

In *Howard's* method, which is appropriate if the patient's arms cannot be made use of, the anæsthetist kneels astride the patient's body facing his head. With his thumbs resting on the xyphoid cartilage and his fingers grasping the free margin of the thorax, the anæsthetist presses upwards and inwards towards the diaphragm, at the same time lowering himself towards the patient's chest. Pressing this for a few seconds, he produces expiration and then suddenly pushes himself up, when inspiration is effected by the elasticity of the patient's chest.

Schäfer's method is perhaps the most effective of all, but can rarely be applied clinically. For drowned persons it should always be first choice. It resembles Marshall Hall's in that the patient is laid prone and expiration is produced by pressing on the back. The operator kneels facing the patient's head. Then with the hands still in position the operator slowly raises himself, removing the pressure from the chest and allowing inspiration. " In other words, sway your body slowly forwards and backwards upon your arms twelve to fifteen times a minute without any marked pause between the movements." [1]

Undesirable Conditions caused by Failing Circulation

The chief causes which lead to serious circulatory failure during anæsthesia are *traumatic shock, hæmorrhage* and *toxic effects of the anæsthetic.* Minor causes are the position of the patient and a loaded stomach. A rare but potent cause is the

[1] " Report of Committee Roy. Med. Chir. Soc.," 1904, Vol. 87.

status lymphaticus. It is obvious that the condition of the patient before operation will to a large extent determine the action of these causes. Thus the very anæmic, those with serious respiratory difficulty, particularly if this is due to acute disease such as pneumonia, and those with fatty, poorly acting or dilated hearts, are more easily put into danger than the healthy. Patients who are extremely nervous beforehand are probably more easily affected even during anæsthesia than those who approach operation with an untroubled mind.

Shock, the most common cause in practice of serious circulatory failure, may be present before the administration is begun, or more frequently may come on during operation. There is a difference between these two forms. Mann [1] has shown that it is impossible to reduce the anæsthetized animal to a state of shock by any degree of sensory stimulation, provided that hæmorrhage is prevented and the abdomen is not opened. This is, of course, in direct opposition to Crile's theory of shock from the central effects of violent nerve impulses, and the same observer's contention that the vaso-motor centre is fatigued or depressed in shock is controverted by Mann. He finds that this is the most resistant of all the vital centres, and that though the respiratory centre is more quickly injured than any other vital centre by shock, yet this centre is not responsible for the condition, and shock is not due to disturbance of the respiration. Mann and other observers have shown that in the laboratory the easiest and most certain method of producing shock is exposure and trauma of the abdominal viscera. Shock thus produced is not due alone to a paralysis of the vaso-motor mechanism of the splanchnic area. The cause is the tremendous loss of red cells and fluid from the blood, due to the reaction of the splanchnic area to irritation. The factors involved in this irritation do not especially involve the nervous system. The actual **condition of the blood and its vessels in shock** as well as its essential causes have been the subject of much controversy. Knowledge as to both has been greatly increased by vast clinical experience and much experimental work during the war years and after. The following condensed account depends mainly on the work of Leonard Hill, Stirling, Crile, Cannon, Bayliss and Frankau. In order to treat in the best possible way those of his patients who are affected by shock the anæsthetist must have a clear understanding of their condition. Shock has been described (Rendle Short) as "depressed vitality due to traumatism." Traumatism must be held to include not merely mechanical injury inflicted by accidents or surgical operations, but also the damage produced by rupture

[1] *Johns Hopkins Hospital Bulletin,* July, 1914.

of a viscus or by violent emotional disturbance, by cold, or by bodily fatigue. Shock may be **primary,** an immediate phenomenon due to violent stimulation of some part of the body. This is the form of shock common in war, but uncommon in civil practice, when its usual causes are serious accidents, extensive burns, or sudden stimulation of the peritoneum from the perforation of an ulcer or appendix abscess. **Secondary shock,** the form more commonly met in ordinary practice, is a slower, more insidious process, and may be due to several factors. The chief of these are generally admitted to be *capillary stasis with increased permeability of the capillary walls, reduction of the total volume of blood in the circulation, deficient supply of oxygen to the tissues,* and *lowering of the body temperature; with these goes pronounced lowering of the blood pressure.* The presence of these factors is commonly admitted. How they come about is matter of dispute. Theories of shock which attributed it to over-stimulation and exhaustion of nerve centres, to paralysis of the vaso-motor centre, to acapnia, to adrenalin deficiency, to acidosis, and to splanchnic pooling of the blood have been held. That the absorption of tissue toxins can produce shock is a recent discovery, and that histamine is the chief agent in many cases of mechanical trauma when much muscular damage is present seems likely. Cannon, Dale and Bayliss found that a poison from pulped muscles caused a fall in blood pressure even when the nerve supply of the part was blocked and that this fall was prevented if the circulation of the part was blocked. Clinically the amputation of limbs in which there was much muscle damage was found to be effective in diminishing shock. On the other hand, many causes of shock have no relationship at all with muscle poison. Whether shock is immediately caused by nervous impulses or by toxic effects, the condition of the blood vessels and of the blood itself appears to be a prime factor in producing the symptoms. The diminished blood volume in patients suffering from shock has been shown by the vital red method to bear definite relationship to the severity of the clinical condition (Keith). Leonard Hill [1] states that shock appears to be due to metabolic products opening up all the capillaries and increasing imbibition in all the cells of the body at the same time; such products can be evoked in the cells by violent nervous stimulation, by want of oxygen, or by toxic substances in the blood. The same observer has shown that the capillaries that have blood in them are capable of taking up much more blood by dilatation, that there are numerous capillaries in the body ordinarily not filled at all, and that there are anastomotic channels whereby pressure is easily and quickly transmitted

[1] *Lancet*, Feb. 14, 1920, p. 366, and July 9, 1920, p. 65.

between small arteries and veins. It has been repeatedly noted in shocked patients that the red blood cells in venous blood taken from the arm numbered two million corpuscles fewer per cubic millimetre than in blood taken from the capillaries. As shock diminishes the capillary and venous red cell counts approximate in value. The high red cell count pertaining to capillary areas in which there is stasis does not obtain in the direct paths through which arterial blood, with its lower red-cell concentration, flows straight to the veins. The blood in shock is not only stagnant in capillary areas, but its viscosity there is increased. In shock blood slowly concentrates in the capillary area, and the return blood to the heart is a mixture of this concentrated blood with more normal blood passing by direct anastomotic channels to the veins. Any increase of viscosity of the blood has a great slowing effect on the blood current, because the kinetic pressure of blood flow is at most a very few millimetres of mercury. In normal conditions the body maintains the viscosity as constant as it does the osmotic pressure or the hydrogen-ion concentration of the blood. The importance of the blood pressure in the larger arteries, on which so much clinical investigation has been lavished, is, Hill points out, only great in so far as the capillary supply of blood depends upon it. The arterial pressure exists solely for the maintenance of an adequate capillary rate of flow. Owing to arterial tone capillary fields that require, as during violent exercise for example, increased supplies of blood can obtain it by local alterations of arterial pressure without the general blood pressure being affected or the heart being over-worked. There is a critical level of arterial blood pressure below which it must not go for long periods, and that level is determined by the rate of blood flow through the *capillaries of the cardiac muscle.* If the rate of flow in the capillaries of the heart falls below the level required for the supply of energy of the heart muscle grave results ensue. Shock is one of them. If the arterial blood pressure fall for long periods below the critical level the rate of capillary flow falls below the normal. Attempt at compensation is made by increased vaso-constriction (which has long been asserted by Malcolm), and while by this means, succour is brought, by increased pressure in the coronary arteries, to the heart muscle and to the brain, the capillary field in the body generally outside these areas falls from its already low level of a few millimetres of blood pressure to one still lower. Vaso-constriction is no cure for an arteriole blood pressure below the critical value.[1] This explains the failure of adrenalin or pituitrin in cases of shock. The blood pressure question in its bearing on shock may be summed up in these words

[1] *Lancet*, Feb. 14, 1920, p. 366, and July 9, 1920, p. 65.

of Leonard Hill: "Low arterial pressures are dangerous because the capillary kinetic energy of blood flow is very small even with normal arterial blood pressure. There is a very small margin of safety in the capillary area." Crile upheld the view that traumatic shock is due to exhaustion of brain cells by intense sensory excitation, and that by completely blocking the sensory paths the shockless operation could be obtained. The degenerative changes in cortical cells which Crile showed to be present in severe shock have been found by other observers. They have, however, been believed to be secondary to the anoxæmia accompanying shock, and not a causative factor of the condition. Crile's work has been of great practical value for the attention which it directed to the importance of gentleness in surgery, so as to diminish in every way the infliction of severe stimuli, and to the grave effects which toxic anæsthetics can have in aggravating or causing shock. He showed that nitrous oxide and oxygen warded off shock better than ether or chloroform. Clinical evidence has supported his view. Certainly it has shown that for patients already in a state of shock nitrous oxide and oxygen offers a better chance than any other means of general anæsthesia. Crile [1] regards shock as "a state of exhaustion which has been rapidly developed by psychic traumatic toxic or thermal stimuli." He believes that ether anæsthesia offers no protection to the brain cells against the effects of trauma, and that the lipoid solvent anæsthetics probably break the arc which maintains consciousness somewhere in the efferent path beyond the brain cells. The changes in the brain cells which Crile demonstrated were most marked in the cerebellum and the cortex, although present also in the medulla and the cord. They were chromatolysis, rupture of nuclear and cell membranes, and disintegration. Emotion Crile found to cause more rapid exhaustion than exertion or trauma, except that of extensive tissue mangling or of the perforation of viscera. Crile found that after four hours' continuous anæsthesia with ether or chloroform histologic changes appeared in the brain, liver, and adrenals. These changes were similar to those found in shock. Lesions produced by equal periods of nitrous oxide anæsthesia were negligible as far as the brain was concerned, although changes appeared in the liver. The intra-cellular changes of shock revealed by the microscope are paralleled, according to this observer, by alterations in electric conductivity. Crile maintains that the adrenals are factors in the primary cycle of exhaustion, which leads to shock, though their *rôle* cannot be accurately defined. The brain, he finds, is dependent on the functional integrity of the liver, and

[1] "A Physical Interpretation of Shock, Exhaustion and Restoration," 1921.

the liver is in part dependent on the adrenals. Both are dependent on oxidation. Crile attributes to acidosis an importance in the causation of shock which is denied to it by others who regard this phenomenon as a symptom secondary to deficient oxidation. Moore [1] has shown that the presence or not of acidosis depends on the relative rate of working of the respiratory and circulatory systems. Crile maintains that the brain cells alone among the cells of the body are without intrinsic means of protection against acidosis. He states that, whatever the cause, the basic phenomena of shock are—

(1) Muscular and mental weakness
(2) Diminished adaptive metabolism.
(3) Increased respiration.
(4) Increased pulse rate.
(5) Diminished reserve alkalinity of the blood; in acute phases increased H-ion concentration.
(6) Intra-cellular changes in the brain, liver and adrenals.
(7) Decreased electric conductivity of the brain and increased electric conductivity of the liver.

It is noteworthy that Crile believes that the brain may be exhausted primarily while the blood pressure is normal or even higher than normal. His estimate of the part which blood pressure takes in shock is thus in striking contrast with the views of some other authorities to which reference has been made. It appears that, although opinion has become more uniform as to the actual state of the shocked individual, particularly as regards his blood state, the deficiency of oxygen for his tissues and the diminution of the alkali reserve in his blood, yet we have no certain knowledge of the ultimate cause of these phenomena and particularly are unaware of the part which cerebral centres do or do not play in their production. Cliincal observation leads us to believe that injury to some parts of the body produces shock more easily than the same injury to other parts. And it is parts most freely supplied with nerves that are thus susceptible. Also some kinds of injury are more shock-producing than others. Tearing and dragging tissues are more apt to produce shock than cutting them with a sharp instrument. It is noticeable that these forms of injury which produce shock are the forms which we are accustomed to see followed in the anæsthetic patient by reflex effects on the respiration, and sometimes on the circulation too. Whatever other means there may be by which the processes are started which constitute shock, it is clear that violent nervous impulses are certainly one of them.

[1] *Lancet*, Sept. 13, 1919, p. 474.

The *clinical appearance* of the patient suffering from shock is in accordance with the physiological description of the blood state. He is pale, with a sluggish circulation and cyanosis of fingers, ears, and lips. The surface of the body is cool and clammy, the rectal temperature may be as much as 5° below normal. Coolness of the breath can often be detected, and is a grave sign. The pulse is of small volume, of low tension, and rapid, often reaching 140 or more beats per minute. Increased rapidity and smallness of volume in the pulse are often the first indications of approaching shock during operation, unless frequent pulse pressure readings are being taken, when these may give the first warning. In America great stress has been laid on the value of frequent blood pressure estimations as a guide to the early perception of shock during operation. Bourne [1] has divided the circulatory depression which culminates in shock into three degrees. First degree circulatory depression he describes as that in which there is a 15 per cent. increase in pulse rate without change in blood pressure, or a 10 per cent. decrease in blood pressure without decrease in pulse rate. Second degree is that of increase of 25 per cent. pulse rate along with a 10 or 25 per cent. decrease in blood pressure. Third degree, which is definitely shock, shows a pulse rate of 100 or more and rising, accompanied by a rapidly falling blood pressure reaching 80 mm. Hg. systolic and 20 or less pulse pressure. This is known as the McKesson interpretation of blood pressure findings. If third degree depression lasts much longer than fifteen to twenty minutes the chances of ultimate recovery are held to be slight. By taking frequent readings of the blood pressure the anæsthetist is able to warn the surgeon, when second degree depression is manifest, that the patient is approaching a state of shock. The systolic pressure may fall as low as 40 mm. Hg. If not under an anæsthetic the patient in shock lies quiet, with sometimes slight lateral or nodding movements of the head, probably due to deficient aeration of the blood.[2] If a capillary blood count is taken of blood from a finger a concentration of red cells is found. There may be eight instead of five or six million. Compared with a venous count the capillary blood is 10 to 20 per cent. higher. In healthy persons the difference is not more than 1 to 3 per cent.

The **treatment of shock** from the anæsthetist's point of view must be preventive and curative. When there is reason to anticipate its oncoming he must take all possible measures to prevent it, and when shock is present from the first or appears

[1] *Proc. Royal Soc. Med.* (Anæsthetic Section), January, 1922.
[2] *St. George's Hospital Gazette*, C. H. S. Frankau, May, 1920.

during operation he must attempt to correct it. The main needs of the shocked patient are **warmth, fluids, and oxygen.** In order to *prevent shock* the body heat is preserved by proper warming of the table, by the least possible exposure of the patient, and by the administration of warmed vapours. Preliminary hypodermic injection of morphia or omnopon is employed. During the twenty-four hours preceding operation the fluid intake should be increased, and water or sweetened lemon or barley water may be allowed up to within two hours of the administration. At this time in addition a feeble patient should be given a rectal saline. Sedatives are to be used to procure good sleep during the night preceding operation, and everything possible is to be done to promote mental rest. The patient's warmth, comfort, and quiet are to be uninterrupted by any arrangements that have to be made before he is rendered unconscious. During the operation continuous subcutaneous infusion of saline supplies fluid to the circulation. For this purpose Lane's bag (Fig. 44) is convenient. The Trendelenburg position is used whenever possible. All moving of the patient during anæsthesia is avoided if possible, and is carried out gently and without raising the head when he is returned to bed. The choice of anæsthetic is important. Whenever possible nitrous oxide and oxygen should be the general anæsthetic. If the surgeon does not supplement it with local injections it will often not suffice, and then warmed ether is the next choice, unless spinal analgesia with gas and oxygen is suitable. When ether is given the narcosis is to be kept as light as possible compatibly with the surgeon's requirements. Chloroform is the worst anæsthetic to use. When the table is not a warmed one hot bottles must be used, and attention is given in either case to the proper garments. A thick flannel pyjama suit with long woollen stockings and a thick pad of cotton-wool across the chest generally provides the

FIG. 44.

most suitable covering. A table warmed by electricity or by hot water tanks is, of course, much preferable to the use of hot water bottles. When these are the only possible source of heat care must be taken that they do not touch the patient.

The *curative treatment* of shock depends mainly on due provision of warmth and of fluids. Steps for securing the former have been sufficiently indicated. Saline infusion is now of little use; it has been shown to leave the circulation too quickly. Moreover, to infuse it under the skin is of no avail, because the circulation is not active enough to take the fluid up. Intravenous infusion must be made of Bayliss's 6 per cent. gum solution in normal saline. This has the same viscosity as blood, is a colloidal solution, and yet does not pass rapidly through the capillary walls. It is to be run in slowly at the rate of 30 c.c. per minute, and 600 to 800 c.c. are to be infused. The head is to be kept low and oxygen given with the anæsthetic as soon as shock begins to show itself. The more pronounced the shock the less anæsthetic is required. At the same time it is important to be sure that anæsthesia is always complete. An insufficient narcosis is itself dangerous besides probably interfering with the surgeon's facility. Complete anæsthesia helps in the avoidance of shock, for it protects the brain to a large extent. The futility for this purpose of other anæsthetics than nitrous oxide and oxygen, maintained by Crile, is not borne out by clinical results. "General anæsthesia of moderate depth prevents painful impulses from affecting the nerve cells of the central nervous system" (F. C. Mann, *loc. cit.*). On the other hand, excessive use of the anæsthetic, particularly if this is chloroform, is a potent aggravation of shock. This baneful influence is most severe when shock is associated with sepsis. When nitrous oxide has been the only anæsthetic used, liquids can be given by the mouth directly after operation, and this is an advantage, for the restorative effect of liquid taken through the stomach appears to be greater than if it enters by any other route.

The injection of adrenalin to raise the blood pressure produces a merely transitory effect, if any. Pituitrin has been shown by Mummery [1] to be more effective. No drug, however, is of any importance compared with the effectual application of warmth and of fluid. Strychnine is dangerous and alcohol of slight service. When with shock there is associated hæmorrhage the transfusion of blood appears to be the most effectual remedy. For this purpose the presence of a suitable donor is necessary. The direct method, from an artery of the donor to a vein of the recipient, or the indirect method is employed. In the latter case

[1] *Brit. Med. Journal,* Sept. 17, 1910, and *Lancet,* March 18, 1905.

use is made of Vincent's tubes. The operation of blood transfusion does not, however, generally fall to the anæsthetist, and for details of its performance the reader should consult a surgical work.

The operations in civil practice during which **shock is most to be apprehended** are extensive **intra-abdominal procedures, operations involving the spinal cord and complete removals of the breast.** Operations involving dragging on the kidney, and indeed forcible traction on any viscus, are also especially liable to produce shock. The anæsthetist must, however, bear in mind that reflex shock may be caused during almost any operation and is more likely to be seen during chloroform anæsthesia than during that of ether or nitrous oxide. Many examples might be quoted, but one will be enough to illustrate what is meant. I have purposely chosen an instance in which the operation was not a severe one and in which the anæsthesia at the moment when shock occurred was not one due mainly to chloroform. Similar occurrences are common when chloroform is employed and the operation is severe. It is easy to regard them as simply chloroform over-dose or else as ventricular fibrillation due to chloroform. They are neither, but are reflex effects, and probably cardio-inhibitory. The following instance and others like it prove that sudden circulatory failure may occur without being the result of an over-dose of the anæsthetic. Often the circulatory failure is brief and incomplete, when it scarcely deserves the name of shock. In other instances, as in the following, the condition, although it lasts but a short time, is quite comparable to that of primary wound shock, and may fairly be regarded as having the same origin.

A boy of fourteen, slight build, dark hair, lively disposition, of good health except for frequent bad throats, was to have tonsils and adenoids removed. Examining him, I found a rapid pulse, attributable to anticipation, and nothing else abnormal. He had no preliminary alkaloid injection. He was given C.E. mixture on a Skinner's mask, and, except for a little quiet weeping at first, induction was without incident. There was no excitement stage obvious and no movement; open ether was substituted for two or three minutes. The mouth was opened by a Doyen's gag for the operation to begin. At this time the colour was normal, pupils small, breathing quiet, corneal reflex just absent, *i.e.*, early surgical anæsthesia of normal character. The right tonsil was enucleated with the guillotine, firm but brief pressure being made backwards into that side of the pharynx by the operator in order securely to engage the tonsil in the ring of the instrument. The tonsil was brought away complete. Immediately after the face suddenly paled, the lids of the eyes parted, showing the sclerotic, the pupil dilated to its fullest extent, barely a rim of iris being visible. The wrist pulse was imperceptible and the breathing ceased. The chest was compressed three times. Spontaneous breathing started, the colour came back with a rush, the pupils contracted,

and the operation was finished without anything further unusual occurring, the other tonsil and a mass of adenoids being removed.

The condition of this patient at the moment of the circulatory failure was certainly not one of over-dose with anæsthetic, nor could the interference with breathing caused by the operation, brief as it was, be regarded as the cause of the shock which ensued. The effect on the circulation was as severe as it was, fortunately, brief. It is probable that a similar effect could not be recovered from by a poorly acting heart or by one fully under the influence of chloroform, and no doubt some fatalities during anæsthesia are explicable in this way.

It is interesting to note that certain procedures traditionally supposed to cause shock are generally free from it during the anæsthesia of modern surgery. Thus, dividing the spermatic cord during castration and severing the optic nerve in eye enucleation were long looked upon as very apt to cause shock. Under ordinary ether anæsthesia the author has never seen shock caused by either of these proceedings.

The *choice of anæsthetic* when shock is present before administration begins is most important. The wide experience of giving anæsthetics to shocked patients in war surgery taught clearly that the risk was enhanced least of all by the use of nitrous oxide and oxygen, that chloroform was the worst agent to use, and that spinal analgesia was also very dangerous when shock was already present. This is no doubt due to the lowering of blood pressure which almost invariably occurs with this method. Warmed ether appeared to be next best to gas and oxygen.

Severe *hæmorrhage* occurring during anæsthesia will bring about a state of shock. Actually in practice there are generally at work at the same time as the bleeding other contributory factors. The anæsthetist must be chary of his anæsthetic when there is much bleeding. Rapid pulse and pallor will show the effect that the loss of blood is having. Nothing which is in the anæsthetist's province can be done directly to check hæmorrhage or its effect, except that by avoiding all congestion and too free use of ether he lessens the chance of bleeding, and by diminishing his anæsthetic, particularly if he is using chloroform, he diminishes the evil effects of the hæmorrhage. Whether transfusion is to be employed at once or not depends generally on the severity of the loss ; if this is not very severe, it is sometimes desirable to postpone transfusion, which may by its effect on the blood pressure start fresh hæmorrhage when the source of the bleeding cannot be securely blocked. Infants, anæmic and aged patients, are more easily shocked by loss of blood than others. The occurrence or not of bleeding after operation, as for example after removal of

tonsils, depends to some extent on the anæsthetist. Whenever there is a chance of bleeding occurring later, as there must always be if the operation leaves a considerable raw area anywhere, the anæsthetist should be certain that narcosis is light, and that the blood pressure has returned to about normal, before the patient leaves the theatre. Hæmorrhage can then show itself, whereas if the patient is still very deeply under the anæsthetic he may appear to be safe from bleeding ; but this may start hours later when the circulation recovers its force. Secondary hæmorrhage after circumcision of infants has often been due to lack of this precaution.

Hæmorrhage may occur during operation at some point that is out of sight. The sudden onset of shock may then appear inexplicable and remain so until *post-mortem* examination shows what has happened. The rupture of an aneurysm into the air passages or into the pericardium is an example. In a remarkable case related by Ernest Playfair [1] a varicose vein ruptured at the junction of stomach and œsophagus and *post mortem* blood was found in the air passages from the larynx to the bronchioles. Intense cyanosis, for which no cause was obvious, was the most marked symptom of the accident. Blood escaped from the mouth when the patient was inverted, but there had been no reason to suspect blood in the respiratory tract. Presumably it was inhaled there from the amount poured into the mouth.

The occurrence of *circulatory failure dependent upon the position of the patient* is not very infrequent, although the sequence of cause and effect may easily be overlooked. In most instances the circulatory failure is probably in reality a secondary result of imperfect respiration caused by the position. In other instances, however, it is an immediate result of cerebral anæmia which follows raising the head in a person whose vasomotor system is still deeply under the effects of an anæsthetic (see p. 59). The compensatory effects which allow the conscious individual to be placed in any position without sudden undue accumulation of blood in the dependent part are, as Hill has shown, not working during deep narcosis. During that state sudden raising of the head and shoulders can fatally deplete the brain. A good instance of the damaging effect of a faulty position is related by Apperley.[2] Here the position was the Trendelenburg, one which in most instances is highly favourable for avoiding circulatory failure. That it had the opposite effect with this particular patient was probably due to the fact that it gravely interfered with her respiratory freedom, an effect which this position may exert in

[1] *Lancet*, Dec. 13, 1919.
[2] *Proc. Roy. Soc. Med.*, Vol. 12, No. 7, June, 1919.

the corpulent. The patient was a stout woman in whom laparotomy was being performed for pelvic inflammation. She was under open ether. After the abdomen had been opened the table was tilted into the Trendelenburg position. The pulse immediately stopped, the pupils dilated widely, and the face became pale. No pulsation of the abdominal aorta could be felt. The surgeon squeezed the flabby heart through the diaphragm and the table was made horizontal. In about a minute and a half the heart beat again. The operation was finished normally. Towards the end the table was tilted as before. The pulse at once became irregular, becoming normal again directly the table was made horizontal. It has often been noticed that alterations of position in patients already suffering from shock immediately depress the already lowered blood pressure.

Circulatory Failure depending on the Toxic Effects of the Anæsthetic

Just as in practice surgical shock is usually more or less complicated by the effects of the anæsthetic in use, so, too, the results of over-dosage and consequent toxic paralysis of nerve centres from the anæsthetic are practically never seen free from allied effects of operation. In the laboratory the pure results of over-dose can be produced and studied by themselves. Partly from the lessons there learned we recognise the effect that the anæsthetic is having when these symptoms appear on the operating table. From the physiological laboratory we know that sudden failure of the circulation may occur, not from over-dose, but in early chloroform narcosis. This is in practice the form of failure met more frequently than that due to prolonged excessive administration. A certain proportion of the fatalities due to chloroform have taken place before any operation had begun. In others it is clear that the narcosis at the time of failure was a light one and not associated with excessive inhalation. The influence of proper respiration must also never be lost sight of, for if the breathing is embarrassed or stopped an intake of chloroform, which would be safe with proper elimination, may become dangerous. Some of the instances of sudden circulatory failure after the administration had ceased are doubtless to be explained in this way. Temporary cessation of breathing prevented elimination, and the intaken chloroform amounted to over-dose because none was eliminated.

The circulatory failure that occurs from *over-dose* in practice is not generally a sudden affair. The patient has been growing paler, the respiration feebler, and the pulse more rapid, or else

slow and irregular before its complete arrest. When, however, the anæsthetic is given in too massive concentration, circulatory failure may be sudden. Failure due to toxic action of the anæsthetic is commoner with chloroform than with any other drug, but it occurs after too free use of ether throughout long operations.

The *treatment* of this form of circulatory failure is directed to eliminating the anæsthetic as quickly as possible and restoring the blood supply to the brain. The immediate steps to be taken are—

(1) Lower the head.
(2) With mouth opened and tongue drawn forward, compress the chest.

If recovery does not begin after two or three squeezes of the chest,

(3) Do artificial respiration by Silvester's method.

If after five full minutes of this treatment the pulse cannot be felt, **cardiac massage** must be performed. It is to be noted that five minutes make a much longer time than is generally realized by those working on a moribund patient. They must not rush at cardiac massage, particularly if the abdomen is not yet opened by the operation, and should note the time, not guess at it. There appears to be no doubt from the recorded cases that in cardiac massage we have a means of restoring the heart beat when no other available clinical means is successful. Short of direct massage of the heart efficient artificial respiration is our best remedy, and this fails only when the circulation has actually ceased. In most instances of sudden heart failure on the operating table, although the pulse is not to be felt, the heart has not really completely ceased beating. Artificial respiration and the lowered head will save these patients if immediately applied. In some of the instances in which the restoring of the circulation has been accredited to heart massage it is probable that the restoration would have taken place merely with artificial respiration. There are other instances in which there is no doubt that artificial respiration had been perfectly efficiently tried and that only massage of the heart saved the patient's life. One excellent example is related by Mollison,[1] in whose paper the reader will find a table of fourteen successful cases. Mollison estimated that in his patient the heart had stopped for not less than thirteen and not more than twenty-four minutes before massage was applied. That complete circulatory failure had occurred is made almost certain by the symptoms during recovery, which showed

[1] *Proc. Roy. Soc. Med.* (Anæsthetic Section), Vol. 10, No. 2, December, 1916.

damage to the cerebral tissues, which would be expected from temporary curtailment of their blood supply. The boy was more or less unconscious for seven days after the operation and cardiac massage. For ten days he had rigidity of the limbs or choreic movements. For about twelve days he had incontinence of fæces, and for fifteen or sixteen days incontinence of urine. He had other symptoms of severe cerebral irritation, attributed to the damage done to the brain by the cessation of its circulation. He made a complete recovery after about six weeks. In this patient the circulatory failure occurred after removal of tonsils and adenoids under a mixture of chloroform and ether, and the abdomen was opened for the performance of cardiac massage.

Cardiac massage can be carried out on an infant or young child without opening the abdomen, although the manipulation then is not applied to the whole heart. In an adult any attempt to compress the heart between a hand pushed up below the costal arch and one on the chest is probably quite ineffective. The abdomen must be opened if the heart failure occurs during an operation for which this has not already been done. The massage is then carried out by the sub-diaphragmatic or the trans-diaphragmatic route. The former is recommended by Norbury,[1] whose full paper should be consulted. The thoracic route, although it has been successfully employed, involves a more damaging operation, and is not to be recommended. For the sub-diaphragmatic operation "a hand is inserted between the diaphragm and the left lobe of the liver. The heart is defined and may be pressed against the posterior thoracic wall, external counter-pressure being maintained with the other hand against the ribs over the left side; or else the heart may be kneaded through the diaphragm by the closed fist. The opening in the abdominal wall should be large enough to admit the hand completely." When the abdomen is not already opened the incision should be made in the middle line, or vertically through the upper part of the left rectus, splitting the muscle. Artificial respiration is to be carried on while the heart is being massaged.

For the *trans-diaphragmatic* method, which is strongly advocated by Bost and Neave,[2] but is not generally to be preferred to the sub-diaphragmatic, an incision beginning an inch to the left of the mid-line is carried outwards behind the costal margin, cutting the fibres of the diaphragm near their insertion. A blunt instrument is pushed in to open the pleural cavity, and the opening is dilated by two or three fingers of the right hand. The whole hand can then be passed into the thorax in front of the

[1] *Lancet*, Oct. 4, 1919, p. 602.
[2] *Indian Med. Gazette*, February, 1919, p. 50.

pericardium. The hand is passed upward, the thumb behind the sternum and the fingers embracing the whole heart in the pericardium. Norbury points out that it may be necessary to continue rhythmical compression of the heart for several minutes before spontaneous contractions occur. In one case the heart was massaged for thirty minutes before it could be made to beat. The heart, whether grasped through the diaphragm or directly, after this has been incised, is to be steadily squeezed about seventy times a minute. The physiological effects of cardiac massage have been experimentally investigated by Levy.[1] He concludes that the explanation of the action of massage is the production of an artificial circulation through the coronary arteries. In this way the ventricles are enabled to exert their natural tendency to a rhythmic beat. Levy states that successful performance of massage depends on the efficient compression of both ventricles and an efficient system of artificial respiration. Continued rhythmic compression should be tried first, and if this is not successful after ten minutes, it should be intermitted by intervals of forty-five seconds and less. The first use of cardiac massage as a means of resuscitation is to be credited to the physiological experiments of Schiff in 1874. The first record of its successful application to the human subject appears to be that of Igelsrud in 1901, which was followed in this country by a success in the hands of Lane and Starling.[2]

Henschen [3] claims to have revived the heart, even after the failure of massage, by injecting epinephrin into its substance. Crile too has shown that adrenalin injected into the wall or cavity of the heart can cause contraction. Lockhart Mummery [4] regards adrenalin as the most powerful agent for restoring the apparently dead. From experimental work he finds the most efficient method to be the infusion of saline solution with adrenalin (1 in 50,000) into the veins, and says that the heart is automatically stimulated by distension of the right auricle. Cranston Walker [5] has had success with the injection of adrenalin into the heart muscle. Attempts had been made without avail to revive this patient by cardiac massage. The heart started beating directly after the adrenalin injection, and recovery followed.[6]

Resuscitation by *electrical means* has been demonstrated experimentally by Robinovitch, and may well become of service in practice. The Leduc current is used. This is a current

[1] *Heart*, Vol. 7, No. 3, April, 1920.
[2] *Lancet*, Nov. 22, 1902, p. 1397.
[3] *Journal Amer. Med. Assoc.*, June 5, 1920, p. 1610.
[4] *Brit. Med. Journ.*, Jan. 15, 1921.
[5] *Ibid.*, Jan. 8, 1921.
[6] See also a case in *Brit. Med. Journ.*, Feb. 4, 1922.

interrupted 100 times a second by a special commutator. The anode is placed at the lower part of the spine, the kathode at the upper part of the dorsal region.[1]

The injection of drugs subcutaneously or into blood vessels for the treatment of the kind of circulatory failure we are considering is useless. It is also dangerous if it involves taking up time which should be given to the efficient performance of artificial respiration. The anæsthetist must make this and the proper position of the patient his main business. If while he is securing these two essentials an assistant can make an injection, then pituitrin intramuscularly or intravenously may be helpful directly the circulation begins to recover. Experimentally Crile has restored cardiac pulsation by forcible injection of adrenalin into the carotid artery in the direction of the heart. Apparently the fluid entered the coronary arteries and directly stimulated their walls. A coronary circulation thus started led to ventricular contraction. In practice injection of adrenalin or of any other drug is to be relegated to a second place. Until some circulation is in progress the injection into a vein or muscle or beneath the skin is obviously useless. When the heart has been restarted adrenalin is regarded by some authorities as harmful. Pituitrin or strychnine are the most likely drugs to be of service. When slowly produced shock has played a part in causing the heart failure strychnine is to be avoided.

Vomiting as a cause of circulatory failure is sometimes seen during and sometimes after chloroform anæsthesia. The pallor which immediately precedes vomiting during narcosis is a familiar phenomenon to the inexperienced administrator of chloroform, and, with the accompanying shallow breathing and dilated pupil, makes a picture which readily misleads him into the belief that he has given an over-dose. However, directly the effort of vomiting is over the colour returns and vigour of pulse and breathing are re-established. Such an attack is never fatal unless there is some abnormal weakness of heart or vaso-motor system in the patient, or unless he is—which is most exceptional—suffering from shock or deep chloroform narcosis when the vomiting takes place. The strain thrown on the right heart from the interrupted respiration due to the laryngeal closure during the act of vomitiug may then prove fatal (see p. 341). The danger of giving anæsthetics to persons with undigested food in the stomach lies in the probability of vomiting being started. When a meal is known to have been recently taken the stomach should be washed out as soon as anæsthesia is obtained and before the operation is begun. When vomiting occurs during anæsthesia the head

[1] *Lancet*, July 10, 1910, p. 97.

should be kept low and to one side, the mouth half open with a gag, and no attempt should be made to push forward the lower jaw, since this tends to open the larynx and create a facility for inhaling vomited material.

Status lymphaticus, sometimes called lymphatism or status thymicus, has frequently been associated with sudden and fatal circulatory failure during anæsthesia. The relationship between the condition and the event is, however, not at all clear. Moreover, it is certain that to many deaths occurring during narcosis the explanation of status lymphaticus has been attributed when the *post-mortem* finding did not justify the term. Status lymphaticus is a condition which has often been found *post mortem* in young persons and children who have died suddenly from quite trivial causes. Obviously, therefore, in a patient so afflicted death might occur during the inhalation of an anæsthetic or the performance of an operation. On the other hand, in at least one instance a patient who died during anæsthesia and was found *post mortem* to have status lymphaticus had previously passed through several administrations of anæsthetics without untoward symptoms. Either, therefore, the condition was of quite recent development, which is unlikely from the pathological lesions, or else the subject of lymphatism need not necessarily die because he takes an anæsthetic. The latter is probably the truth, and it is pretty certain that children subject to this condition often take anæsthetics without harm. The nature of the anæsthetic given most certainly plays a part, and the great majority of deaths have occurred during chloroform anæsthesia. In fact, the writer has not found a single record of status lymphaticus death under ether that can be accepted without reserve. At the same time it must be remembered that the deaths have mostly been among children, for whom in the past ether was rarely employed. Status lymphaticus is rarely recognized in life. It has never yet been diagnosed beforehand in a patient who has died under anæsthetics. Yet the evidence *post mortem*, when the condition is fully developed, is abundant. Paltauf, who first gave a full description of this disorder (1889), mentioned enlargement of the tonsils, of the lymphatic glands generally, of the follicles at the base of the tongue, of the spleen, and of the thymus gland, with anæmia and, in most cases, a narrowing or under-development of the aorta. In adults with status lymphaticus the thymus is persistent, whereas normally it withers at puberty. In children it normally weighs about 10 grammes; in patients with status lymphaticus it has weighed 56 grammes. The enlarged or the persistent thymus can be detected by X-rays, and herein lies the best chance of detecting lymphatism during life. Enlargement of glands and

of tonsils is so common from other causes that their detection gives no certain indication of lymphatism. The extra dulness behind the sternum caused by the enlarged thymus appears to be difficult to ascertain. It is stated that if the triangular area of dulness, with its base at the sterno-clavicular level and its apex at the level of the third rib, extends 1 centimetre beyond the sides of the sternum, it represents an enlarged thymus. Pushing downwards of the upper border of the superficial cardiac dulness is regarded by some as the most certain sign. The thymus is not, however, always enlarged. In some instances it has not been present at all, being replaced by fatty tissue mistaken for the gland.[1] Spilsbury lays stress on the presence in the heart muscle of fatty degeneration or brown atrophy, or both together. Enlarged thymus has been found with exophthalmic goitre. Some of those suffering from this complaint appear to be also subjects of lymphatism. The late Salisbury Trevor informed the writer that he regarded the presence of enlarged follicles on the laryngeal aspect of the epiglottis as a very constant sign of lymphatism. Trevor had a wide experience of *post-mortem* work and was very careful before he attached the description of status lymphaticus. A good account of the *post-mortem* appearances in a typical example is given by him.[1] Farquhar Buzzard [1] has drawn attention to an affinity between the disease known as myasthenia gravis and lymphatism. In both there may occur sudden death from trivial causes, and in both the thymus may be abnormally large. Moreover, in myasthenia there are found scattered through many of the tissues and organs of the body small clumps of lymphoid cells. At present our knowledge does not allow us to give any reason for the lesions found in lymphatism, and still less for the sudden deaths for which they are presumably responsible. The view most widely held is that the general hypertrophy of the lymphatic tissue is probably the expression of a chronic toxæmia and that death is caused by a process analogous to anaphylactic shock. It is supposed that there is a sudden release of toxin from the lymphoid tissue in a sensitized individual. With regard to death in a lymphatic subject during anæsthesia, there are two complicating factors not to be ignored. Firstly, there are the enlarged tonsils and general lymphoid hypertrophy in the fauces, rendering the subjects easily liable to local mechanical obstruction of respiration, and secondly there is the degeneration of cardiac muscle and poor arterial development, conditions which we may presume would render any respiratory embarrassment unusually effective in leading to circulatory failure. Therefore, when death occurs in a subject of status

[1] *Proc. Roy. Soc. Med.* (Anæsthetic Section), Vol. 3, 1910.

lymphaticus, we should be able to rule out this comparatively simple explanation, interrupted breathing and secondary heart failure, before we fall back on the mysterious, unknown effects of the condition itself. The subjects of this state appear to be always children or young adults. The latter are often over-tall, but weedy. The treatment for circulatory failure due to status lymphaticus should be on the same lines as that described for the failure due to anæsthetic toxic effects. The reader interested in lymphatism should consult Bellamy Gardner's paper and the subsequent discussion at the Royal Society of Medicine.[1]

[1] *Proc. Roy. Soc. Med.* (Anæsthetic Section), Vol. 3, 1910.

CHAPTER XIX

ACCIDENTS AND COMPLICATIONS THAT MAY FOLLOW ANÆSTHESIA

AFTER-CARE

THE common effects that may follow chloroform, ether, nitrous oxide, and ethyl chloride are described in the chapters dealing with those drugs. There are other rarer complications and accidents that may follow on anæsthesia which must now be given notice. The most important concern **vomiting** when it takes place in the still insensitive patient. This may be the cause of catastrophe either through *syncope* or through *asphyxia*. The former accident is only to be feared when chloroform has been the anæsthetic employed. In persons whose heart action is weak the sudden strain that is thrown on that organ by the effort of vomiting, with its concurrent interruption to respiration, may, acting in conjunction with the chloroform effect on the cardiac muscle, bring the heart to a standstill. It is highly probable that when this occurs it is through ventricular fibrillation, which can, we know, be easily excited during light chloroform narcosis. It is during the light narcosis of recovery after the anæsthetic has been withdrawn that these accidents have been recorded According to Levy's experimental work, any stimulus to the heart when it is lightly narcotized with chloroform may cause the ventricles to beat irregularly or to go into actual fibrillation. The clinical conditions when a patient recovering from chloroform anæsthesia but not yet conscious starts to vomit parallel very closely those of Levy's laboratory experiments. Fortunately the human heart rarely enters into irrecoverable fibrillation under these conditions. It is probable, however, that just as the cat's heart will frequently recover from the beginnings of fibrillation, so, too, the many patients whom we see pale and with poor pulses at the vomiting period of recovery are also examples of the recoverable stage of fibrillation. The rare instances of fatality appear to correspond closely with the irrecoverable fibrillation induced in the laboratory. An example of this sudden heart failure directly consequent on the act of vomiting after chloroform anæsthesia was the following :—

The patient was a boy of twelve, thin and weakly, but not known to suffer from any definite disorder till the attack of acute appendicitis for

which he was operated on. After induction with "gas and ether" chloroform was used, and nothing unusual occurred during the operation, which lasted thirty minutes and consisted in the removal of an acutely inflamed swollen appendix. At its conclusion the boy was pale, but normally his colour was poor, and no anxiety was felt as to his immediate safety. He was carried back to bed and placed on his right side with the head slightly raised. Breathing was quiet but regular, the pulse was not extraordinarily feeble, and the corneal reflex had returned. Both surgeon and anæsthetist left the boy, a nurse remaining by his side. A few minutes later he vomited, and his appearance alarmed the nurse, who called for help. The doctors returned at once to the bed and found the boy dead. The face was pale and the pupils widely dilated. Artificial respiration and strychnine injection at once applied were of no avail, although a few breaths were drawn spontaneously. The vomited matter was bilious fluid, small in amount, and there was no evidence at the time or on *post-mortem* examination that any vomited matter had entered the air passages. A complete *post-mortem* examination was not made.

It is difficult to see how any treatment except direct cardiac massage could have saved this patient, and under similar circumstances that would be, no doubt, the proper course to pursue if it could be adopted within a few minutes. Other instances of syncope during the recovery stage of chloroform anæsthesia have been recorded, but the association of the heart failure with the act of vomiting has not been as clear as it was in this instance. More often there has been a strong probability at least that the collapse has been associated with obstructive asphyxia, either from spasm or from foreign matter, and that the case belongs really to the class next considered. In this category come the not very rare cases in which a child has succumbed after it has passed safely through the operation for removal of tonsils and adenoids.

Asphyxia from inhalation of vomited matter has on several occasions caused death during recovery from anæsthesia, and is not to be feared after one anæsthetic more than after another. It is the possibility of this occurrence which makes the proper posture of the unconscious patient of such vital importance. If the patient is lying on the side with the head not raised, then, even if vomiting occurs in the absence of any attendant, foreign matter is unlikely to enter the larynx. When asphyxia has ensued upon the vomiting of a patient beginning to come round from an anæsthetic it has usually happened that the patient has been lying on the back with the head in the middle line. The stage of recovery being arrived at when vomiting may occur, this has come about. The larynx has not been yet sufficiently insensitive to eject at once the entering matter, which has either been further inhaled with fatal result or has set up glottic spasm and so caused asphyxial death. It has not been necessary for the inhaled matter to be solid, or even in much quantity if liquid,

nor, in fact, need there be actual vomiting. Asphyxia can arise, if the patient is lying in a faulty position, merely from the *spasm* of jaw muscles and of tongue and fauces which characterizes light narcosis in some individuals. With teeth clenched and tongue swollen and spasmodically retracted, the upper aperture of the larynx may be so effectively blocked as to render respiration impossible. The presence of blood or of mucus and saliva in the fauces exaggerates the spasmodic arrest of the breathing. In this condition the patient's appearance immediately suggests the necessity for treatment, and this, fortunately, is rapidly effective. Fatalities have occurred chiefly when aid has not been forthcoming soon enough, as, for instance, when a patient has been put back to bed in a large ward and left unattended until some neighbouring patient, alarmed by the blue-black face of the recent arrival, has called the nurse to him from the far end of the room too late.

A healthy labourer, having ruptured himself while at work, was operated on for radical cure of the hernia. "Gas and ether" was the anæsthetic used, and nothing unusual occurred throughout the operation. When he was already coming round and about to be moved from the table, it was remembered that a promise had been made to extract some faulty teeth. The anæsthetic was reapplied, full anæsthesia obtained, and several teeth removed under ether. The patient was wheeled out of the theatre and back to his bed, some distance away. When he arrived in the ward the nurse became so alarmed at his appearance that medical help was sent for. The house surgeon arriving found the patient lying on his back, with jaws clenched, face deep purple, blood and froth oozing between the teeth, and respiration at a standstill. No remedial measures availed to restore life. *Post mortem* a little blood and mucus were found in both larynx and trachea. The heart and lungs presented all the appearances usually found after death from asphyxia.

There can be little doubt that, had some one been present to open the mouth, pass a finger to the back of the pharynx, draw out the tongue, and compress the chest when spasm began, this patient would have been saved. Even if he had been unattended, but lying well over on one side, it is quite possible that the obstruction would not have completely occluded his larynx, and that enough respiration would have been effected to permit complete recovery as the spasm passed off.

The obstruction in cases of this kind is mostly due to the *spasmodically retracted and congested tongue.* In other instances the vomited material has played the chief part, and has been found in quantity in the air passages even to the finer bronchi. So far as circumstances permit, every patient after operation should be placed **on the side,** a pillow being arranged at his back to keep the position. The head is slightly raised on another pillow. Some person able to render help if needed should be

with the patient until he is capable of voluntary movement or has answered to a question or has vomited and has a brisk conjunctival reflex. When there is especial reason to expect spasm during recovery, as there will be when the patient has shown much spasm during induction, a small prop should be allowed to remain between the teeth when the patient returns to bed. If the necessity arises to open the mouth, this can then easily be effected by slipping in a Mason's gag behind the prop. In the absence of a prop, if the teeth are complete and clenched in spasm, a tooth might have to be sacrificed in order to permit the use of a gag. It is sometimes possible to open the mouth, even when clenched in spasm, by stretching back the cheeks and pressing with the thumbs behind the hindmost teeth of the lower jaw. When vomited matter has been already brought up into the mouth, care must be taken that the first breath drawn when the mouth is opened does not inhale foreign material. This is unlikely to happen if the patient is in the lateral position. If he is not, then the fauces should be rapidly sponged out directly the mouth is sufficiently open and before the tongue is drawn forward. The lateral position not only renders unlikely the blocking of the upper aperture of the larynx by the root of the tongue, but also gives mucus and saliva and any vomited material an easy escape into the dependent cheek and out of the mouth. It is the position which has been shown to be safest for all insensible persons, whether unconsciousness is due to anæsthetics or to apoplexy, epilepsy, or drowning.[1]

When the patient is fully conscious he may be propped up into a sitting position. Often there is great advantage in this, but careful watch must, of course, be kept to see that faintness does not arise. If it does, the pillows must be removed and the side horizontal position resumed. The sitting posture helps in avoiding sickness and also makes the act of vomiting less difficult if it occurs. After many abdominal operations it is important from the surgical point of view that the Fowler position, *i.e.*, a sitting posture with pillows behind the thighs, should be adopted. Various devices are in use to keep the patient from slipping down in the bed. A firm bolster behind the knees, a large number of pillows for the back and head, and a skilful nurse can achieve the object.

Apart from the serious consequences that occasionally ensue upon vomiting, it is common for *pallor* and *shallow breathing* to precede the event in the recovering patient. Sometimes these phenomena appear in the partly conscious patient although vomiting does not occur. Brisk rubbing of

[1] Bowles' "Stertor and Apoplexy."

the face and lips soon restores the circulation. The bed into which the patient is removed should be well warmed, but all hot bottles must be taken out before he is placed in it. On many occasions severe burns have been inflicted on patients whose feet or legs have been left in contact with hot bottles during the recovery period. An amount of heat that would do no damage to the conscious patient can hurt the skin of one whose nerves are still under the influence of the anæsthetic. Moreover, an amount of heat that would at once be resented by the conscious is tolerated by the unconscious patient, and damage is easily done in this way. The temperature sense is the sense most easily abolished by anæsthetics and consequently is probably the last to return during recovery. The room should be warm but well ventilated, an open fire and an open window being generally the most convenient means for securing this. No effort need be made to check vomiting that occurs before consciousness has returned. Indeed, some authorities believe that patients do better with than without this, and certainly it serves to remove mucus and saliva impregnated with the anæsthetic that have been swallowed during narcosis. While the patient still lies unconscious or semi-conscious it is a good plan to cover the face loosely with a towel on which is freely sprinkled eau de cologne. The vapour is slightly stimulating, and it helps to lessen feelings of sickness when full consciousness returns. If sickness occurs after this a glass of warm water containing a drachm each of bicarbonate of soda and of sal volatile is to be given. This will probably produce another and often a final vomit. Further sickness is to be treated as directed on p. 217. In case of persistent vomiting the stomach may be washed out with advantage once at least. In some cases of persistent vomiting there is a large nervous element. These patients are best treated by enemata of saline with potassium bromide (a drachm to a pint) and by withholding all food by the mouth until the vomiting ceases. A good example of the efficacy of bromide was afforded by a patient who had taken anæsthetics on several occasions and had always suffered severely from vomiting afterwards. When she came into the author's hands she was to undergo an operation for glaucoma, and it was, of course, highly important that there should be no vomiting afterwards, lest hæmorrhage into the eye should occur. Chloroform was used as the anæsthetic. As soon as she was back in bed she was given an enema of saline with 1½ drachms of potassium bromide in it. Then the patient was put into the sitting posture. Recovery took place without any attempt at vomiting, but the patient complained of a brackish taste in the mouth—due, no doubt, to the absorbed bromide.

The inhalation of carbon dioxide during the recovery period is advocated by Yandell Henderson for overcoming post-anæsthetic depression.[1] According to this authority, it is the insufficiency of the venous return to the right heart that gives to post-operative depression its similarity to the effects of hæmorrhage. Thus recovery of the circulation and rapid return to normal arterial pressure are to be expected from restoration to the blood and tissues of the carbon dioxide lost during anæsthesia and operation. This result he claims to have obtained. The beneficial effects following inhalation of 8 per cent. carbon dioxide were (1) augmentation of breathing, which rapidly ventilates the anæsthetic out of the blood; (2) a powerful stimulant effect on the circulation with rapid restoration of arterial pressure without subsequent relapse or unfavourable consequences; (3) decided decrease of post-operative nausea, vomiting and thirst; (4) restoration of intestinal tone. The method has not yet been employed on a large number of cases, but experience so far certainly suggests that for treatment of protracted circulatory enfeeblement and vomiting after anæsthesia inhalations of carbon dioxide with oxygen would be worthy of serious trial.

Hæmatemesis occurs not very uncommonly after anæsthesia. The blood is ejected in an altered state, a thin, brownish black liquid with many particles in it. It probably comes from the congested mucous membrane not only of stomach, but also of lower parts of the alimentary canal. No serious amount of blood is lost, and the vomiting of this altered blood is not generally associated with a bad state of the patient. The symptom is seen more often after prolonged deep ether narcosis than after other forms of anæsthesia. Hæmatemesis may come on after prolonged vomiting which did not at first show any blood. The usual treatment for vomiting is to be carried out.

Epistaxis and hæmoptysis have both been witnessed during recovery from anæsthesia, but neither of them to a serious degree.

Paralyses of two kinds are found after anæsthesia. One kind is due to *cerebral hæmorrhage* or *thrombosis* occurring during or just after the inhalation. The patient must be treated as for hemiplegia occurring apart from anæsthesia. The condition is fortunately very rarely associated with anæsthetics. Ether has been most often the anæsthetic concerned. In susceptible subjects the raised blood pressure caused by ether, particularly if closed methods are used, increases the likelihood of rupturing a blood vessel. Some authorities believe that ether also increases the probability of thrombosis taking place. The other kind of

[1] *Journal American Med. Assoc.*, March, 1920.

paralysis is due to *faulty posture* during narcosis, and is of purely local origin. It arises from prolonged pressure upon a nerve or nerves, as when in the lateral position the arm is so laid upon that the musculo-spiral nerve undergoes compression between the table and the patient's body. The same damage may be inflicted between the bone and the table edge if the arm is allowed to fall to the side of the table. Other examples have been furnished by pressure on the brachial plexus through the drawing up of an arm during a long breast operation, the plexus being nipped between the clavicle and first rib or overstretched over the head of the humerus. This accident is particularly liable to occur when the head is turned to the opposite side. The cervical nerve roots may then be over-stretched. The sciatic nerve has been over-stretched by injudicious employment of the lithotomy position and the popliteal by improper application of Clover's crutch. The paralysis resulting from pressure on or stretching of nerves during narcosis has always been recovered from, although it sometimes lasts for a long time. A year and a half has been recorded. Loss of sensation as well as of motion may occur. The *treatment* is that proper for peripheral paralysis, but this will not be in the hands of the anæsthetist. It rests with him, however, to prevent these paralyses by altering or calling attention to any position of the patient during operation which may lead to undue pressure on nerves. It is especially in operations, for example, those on the kidney, requiring a lateral position, in those requiring the lithotomy position, and in long breast operations, that foresight is required. In the last mentioned the arm of the affected side should never be raised for long to more than a right angle with the chest. Even after short inhalations of nitrous oxide pressure effects may be observed if faulty position of the patient's arms or legs is allowed. Thus *numbness* with temporary inability to move the fingers may follow in the hands if these are allowed to clutch the rounded ends of the arms of a dental chair, and numbness of one leg may be caused if it is allowed to be crossed over the other while the patient sits taking gas for a dental operation. The best position for the arms during operation is extended alongside the trunk, the hands flat on the table, resting beneath the buttocks. Or they may be kept in position by Paterson's arm-rest, or by turning over them and pinning a fold of the sheet on which the patient lies. When circumstances render this position impossible the arms may be bent across the chest and retained there by safety-pinning the sleeves to the collar or the sleeves together at the wrists. Care must be taken that the upper arms do not flop back and press against the sides of the table. Paralysis of the brachial plexus

owing to long-continued pressure against hard shoulder rests has followed the use of the Trendelenburg position.

Retention of urine sometimes follows anæsthesia. It is common only after operations on the rectum, for instance after pile operations, or operations involving the urino-genitary organs. Unless borne in mind, it may lead to mistaken diagnosis of obstruction with distension after laparotomy. Thus an old woman was operated on for obstruction due to the impaction of a fibroid uterus in the pelvis. The tumour was removed with complete relief to the obstruction. Three days later increasing abdominal distension led to reopening of the abdomen. The distension was found to be due to an enormously distended bladder from which urine had been dribbling away daily, and had thus deceived the nurse into ignorance of any retention.

Loss of speech has occasionally followed anæsthesia. When not part of the symptoms of a hemiplegia from cerebral hæmorrhage or thrombosis, it has been hysterical in nature. In a recently recorded case [1] the neurologist who examined the patient considered that the condition was possibly due to " minute hæmorrhages or some congestion in the brain and was not hysterical." This patient had been under anæsthetics (gas and ether followed by chloroform and C.E. mixture) nearly two and a half hours. There was a certain degree of motor aphasia, but no sensory aphasia. The lesion appeared to be cortical and to be confined to the dorsal part of the third frontal gyrus. Both optic discs were normal, and urine, blood pressure and temperature were normal throughout. Speech slowly improved, but six days after the anæsthetic it was still rather laboured and staccato. The condition steadily improved, but fifty days after operation speech was still slow and deliberate, and the patient found difficulty in talking to strangers.

Attacks of an *hysterical nature* soon after recovering consciousness are not at all infrequent among emotional persons. Delirium lasting for some days has been known to follow anæsthesia. Loss of speech, certainly functional in origin, has occurred after a short inhalation of nitrous oxide, without, however, persisting long.

Delirium tremens, it is well known, may follow upon anæsthesia in a person who has recently been drinking heavily.

Persistent **hiccough** is an inconvenient though not a dangerous phenomenon occasionally subsequent to anæsthesia. How or why it arises is quite obscure, and no treatment seems to affect the symptom until it ceases, for no apparent reason, as suddenly as it arose. In one recorded instance the patient was a " highly

[1] *Lancet*, Dec. 11, 1920, p. 1198.

nervous man of fifty." He was operated on for hæmorrhoids under "gas and ether." Hiccough started two hours after the operation and went on for nine days. Bromide and chloral procured sleep, but on his waking the hiccough was as active as before. The hiccough became less frequent after the first administration of nitroglycerine, two drops in half a drachm of spirits of chloroform, and five hours later stopped entirely.[1] In another recorded instance the hiccough persisted for fifteen days and was only controlled by injections of morphia powerful enough to induce narcosis.

Paroxysms of *sneezing* occasionally inconvenience a patient during recovery from anæsthesia, and may be attributed to the temporary congestion of the nasal mucous membrane.

Post-operative **inflammation of the parotid gland,** sometimes going on to suppuration, occurs more often after abdominal than after other operations. Tuffier[2] has attributed this complication to dryness of the mouth "owing to hunger treatment, rectal feeding, and disturbance in the secreting glandular apparatus of the mouth." The immediate cause is thought to be an upward infection of Stenson's duct. Care of the teeth and mouth generally before abdominal operations and during recovery from them is an essential step to the avoidance of this as well as of other septic complications.

Finally, mention must be made of **accidental effects** that may follow the use of anæsthetics, although not immediately caused by the drugs. Thus, careless use of strong gags may dislodge teeth. Temporary teeth are very easily knocked out in this way when the gag is used in operations for tonsils and adenoids, unless great care is taken when the blades are inserted between the teeth. Again, the pressure of the gag against the cheek, if long continued, may cause ulceration, and I have seen a broad disfiguring scar on a boy's cheek which was due to improper use of a gag at a former operation. Allied to such an accident are the *burns* that may be caused by hot bottles if these are allowed to lie in close contact with the unconscious patient. When the operating table is itself heated, care must be taken to see that the metal table is nowhere in contact with the patient's unguarded flesh. When he is back in bed all hot bottles must be removed, and if continued in use must be placed outside the blanket which surrounds the patient. It is probable that during the action of narcotics on the nerves a burn can be caused by a heat which would not damage the sensitive subject. More potent still is the fact that the insensitive patient will, of course, not

[1] *Brit. Med. Journal*, March 11, 1899.
[2] *Annals of Surgery*, Part 324, December, 1919.

resent a degree of heat which would at once be complained of by the conscious patient. A damaging contact will thus be allowed to continue until consciousness returns, when the trouble is already done.

Another class of accidental after-effects includes the results of *inhalation of foreign bodies*. The foreign body may be a tooth or portion of a tooth, blood clot, or septic lymph or mucus from the fouled healing surface of a nose, pharynx, or larynx. The septic pneumonia that is sometimes the fatal sequel to operations on the nose or larynx must usually be placed in this class. It is due to inhalation either during operation or afterwards of blood or of septic matter. The precautions to be taken to avoid these accidents are detailed elsewhere (p. 258). The inhalation of a tooth or part of a tooth into the air passages may also be fraught with fatal consequences. An incurable bronchiectasis or abscess or gangrene of lung may be caused if the offensive foreign body cannot be removed. Fatal *asphyxia* has been caused by the inhalation of solid material vomited up into the mouth during narcosis, by a forgotten post-nasal sponge occluding the larynx, by a mouth-prop drawn into the larynx, and by the broken-off blade of a tooth-forceps inhaled (see p. 315).

CHAPTER XX

UNUSUAL USES OF ANÆSTHESIA

ALTHOUGH the commonest use of anæsthetics is to allow the performance of surgical operations, it is not their only use. Anæsthetics are used also *therapeutically*, *i.e.*, to alleviate pain, convulsive attacks or respiratory spasms, and also *diagnostically* to obtain complete relaxation of muscles, generally for thorough examination of the abdomen or pelvis. From what we may call the diagnostic use of anæsthetics interesting and valuable results are often obtained. Thus diagnoses made with confidence beforehand are sometimes completely changed when the patient is under an anæsthetic, tumours that have been declared irremovable are found to be mobile and are removed, masses are revealed, the presence of which had been hitherto unsuspected, and operations that had been previously held to be perfectly feasible are found impossible and abandoned. The present writer [1] has drawn attention to the value of examination during anæsthesia in most cases of abdominal tumour, and has related instances in support. Most anæsthetists of experience, in fact, can recall occasions on which the surgeon would have been helped and his action altered by a previous examination during anæsthesia. Sometimes, for example, an abdominal tumour turns out not to be in the region where it was expected or concerned with the organ with which it was supposed to be connected. By not knowing this beforehand the surgeon opens the abdomen at a disadvantage. For instance, a laparotomy was performed and the appendix removed which appeared to be but little concerned in the patient's symptoms, for a fuller examination of the abdomen from within disclosed an early carcinoma of the sigmoid. This was removable, but not through the same incision. This growth would have been felt, as the surgeon observed, by a bimanual examination under anæsthesia. In another patient the abdomen was opened for removal of a growth, but so many and such large secondary deposits occupied the epigastric region that removal was out of the question. These growths would have been palpable with the complete relaxation of full narcosis, though not to be discovered in the conscious patient.

[1] *Lancet*, March 28, 1914, p. 885.

Phantom tumours afford other examples of the diagnostic value of anæsthesia. These remarkable swellings, as is well known, completely disappear during deep narcosis and may sometimes be observed to re-form as the anæsthesia passes away. Moreover, as Sir William Bennett [1] pointed out, the behaviour of these swellings beneath the surgeon's hand during light and deep narcosis is characteristic and enables him to say with certainty that the swelling is due to muscular contraction and not to any real tumour which has evaded his grasp. Protective rigidity of muscle during anæsthesia gives another example of the diagnostic aid which anæsthetics can bring. The rigidity of the abdominal wall in acute disease beneath it is, of course, familiar to all, and is an important element in making a diagnosis. This rigidity usually disappears entirely when the patient is fully under an anæsthetic. In a chronic case there may be a similar rigidity which does not disappear in the same way and which throws light on the site of the abdominal lesion. For example, in a patient with a vague history of long-standing abdominal pain the abdomen could not be easily palpated because everywhere the wall was kept rigid. In deep narcosis this rigidity all disappeared except in the upper part of the right rectus ; this portion of the muscle was tight and rigid while the rest of the abdominal wall was relaxed and moving. Guided by this phenomenon the surgeon opened the abdomen in this area and found a duodenal ulcer which had evidently perforated long since and had been shut off by inflammatory products which had affected the under surface of the anterior abdominal wall. In the region of gynæcology many examples could be quoted, both in connection with the pregnant uterus and other swellings, in which anæsthesia has determined diagnosis. This aid is not limited to abdominal problems The true cause of some forms of **asthma** can sometimes be demonstrated only by the behaviour of the respiration during anæsthesia. It may then become obvious that what was apparently ordinary spasmodic asthma is in reality the altered respiration due to the irritation of a new growth. Whereas the attack of spasmodic asthma is cut short by narcosis, that due to an organic lesion is characterized by a stridor which persists during anæsthesia. Anæsthesia may help to the correct diagnosis of **hysterical contractures** and of hysterical aphasia. Discussing hysterical contractures and paralyses following trivial wounds, Hurst [2] remarks that certain changes in electrical reactions " are often most easily observed under a general anæsthetic, which did not result in complete relaxation of the

[1] *Lancet*, Jan. 4, 1902, p. 1.
[2] *Ibid.*, Nov. 1, 1919, p. 273.

spasm until a stage of anæsthesia beyond that in which consciousness is first lost."

Therapeutically anæsthetics are of use in the treatment of renal and biliary colic. It is not necessary to produce full narcosis, but the analgesic stage is maintained and the patient freed from his agonizing attack. For this purpose nitrous oxide and oxygen acts perfectly until the more lasting sedative effect of the necessary hypodermic injections is at work. The convulsions of eclampsia and of tetanus can be controlled by inhalations of chloroform, and here again the anæsthetist is careful not to bring about a deep narcosis. In eclampsia the patient is at first brought into full anæsthesia. Then the narcosis is allowed to lighten, and the anæsthetic is only given freely again if further paroxysms threaten. When the narcosis has to be kept up for hours, as may occur if operative interference with the pregnancy is not advised, chloroform should give way to open ether or to nitrous oxide and oxygen early in the administration. The spasms of **strychnine** poisoning have been relieved by chloroform, which was not required to a deep degree. Similarly in **tetanus** the spasm will generally subside during a light chloroform narcosis and may remain in abeyance for a long period during which no further anæsthetic is given. On the reappearance of the muscular contraction the anæsthetic is again inhaled. Hewitt [1] records the case of a child who was kept in this way more or less under chloroform for thirteen consecutive days. He also points out that where there is intense spasm of the jaws, neck, thorax and abdomen it may be impossible to administer chloroform without intensifying the condition. Under these circumstances rectal ether would be well worth a trial.

For patients with **weakened heart action** the inhalation of nitrous oxide with 20 per cent. oxygen has been found to produce a favourable effect.[2] The cardiac contractions were diminished in number and increased in efficiency. The gas has also been employed in the treatment of angina pectoris and of vomiting and cough of reflex origin.

The antiseptic properties of ether have been made use of in abdominal surgery, but here the drug is not employed in any way as an anæsthetic, and so we need not enter in detail into the practice. Similarly for pulmonary infections inhalation both of chloroform and of ether has been at various times recommended.

Several interesting examples of the treatment of "concussion aphasia" by ether inhalation are related.[3] The patients have

[1] "Anæsthetics," 1912, p. 223.
[2] Gwathmey, "Anæsthesia," p. 670.
[3] *Lancet*, Nov. 2, 1918, p. 603.

been induced to speak or cry out during the excitement stage. Sometimes several separate administrations have been necessary before the power of speech persisted during normal consciousness. The possibility of arousing speech during light ether narcosis on the part of a person who affected dumbness has been used to further the ends of justice.[1] As the writer remarks, " hitherto what association there has been between **anæsthetics and crime** has been for the benefit of the criminal. Actually such an association is rare in real life, although very common in fiction. . . . Anæsthetics have now been turned in real life against the criminal. They have been used to demonstrate the possibility of phonation on the part of a man accused of murder who steadfastly refused to utter a word for two weeks." The man was given nitrous oxide and then ether. During the excitement stage he exclaimed loudly, and " the physician in attendance was satisfied that he could have talked all along if he had so desired."

As stated above, the association of anæsthesia with criminal actions is as rare in real life as it is common in works of fiction. The erotic dreams that may arise during the narcosis of nitrous oxide have often led patients to assert that there has been such an association. This is one reason why an anæsthetic should never be given without the presence of a third party. Buxton [2] quotes the case of a young lady who, having had a tooth extracted by a dentist during an anæsthesia procured by a doctor in the presence of her father and mother, persisted in her allegations that she had been criminally assaulted by the dentist during the operation. People have frequently asserted that they have been " chloroformed " and then robbed. The presumption is always against the truth of such a statement. There is no anæsthetic that can be rapidly and completely given to a person against his will unless he is overpowered by some one much stronger than himself. Ethyl chloride would be the most serviceable drug for the purpose, but the criminal would have to be armed with suitable apparatus and the knowledge how to use it. Usually, according to the victim's account, chloroform has been used, and he has been rapidly made unconscious by the mere holding of a handkerchief over the mouth. Readers of the earlier chapters of this book will realize that narcosis is not thus quickly or easily obtained by chloroform. Still more difficult would it be to employ ether effectually against the recipient's will. There appears, in fact, to be no clear case recorded in which anæsthetics have helped in the commission of a felony.

[1] *Lancet*, April 16, 1921, p. 819.
[2] " Anæsthetics," 1921, p. 521.

CHAPTER XXI

LOCAL ANALGESIA

SURFACE APPLICATION—INFILTRATION—CONDUCTION—SPLANCHNIC

GENERAL anæsthesia we have seen to be characterized by the presence in the general circulation of the drug on which the anæsthesia depends. We have now to describe those forms of anæsthesia, or more properly analgesia, which depend on the local application of the substances which banish sensibility to pain. This local application may be made to the sensory nerves anywhere from their peripheral endings to their origin in the spinal roots. The simplest method of application is when the anæsthetic is painted on a mucous membrane, instilled into the eye, or merely applied to the skin. According to the site of the injection of analgesics, we speak of *infiltration analgesia* when the tissues themselves are infiltrated with the desensitizing liquid, *regional* or *conduction analgesia* when the nerve trunks are affected and the areas they supply thus deprived of sensation, and *spinal* or *epidural analgesia* when the analgesics are injected into the cerebro-spinal fluid within the spinal canal, or into the sacral canal outside the dura mater. In addition we have *paravertebral* and *splanchnic* analgesia. The object of injection in every case is to affect the nerve tissues, nerve endings or trunks or roots, in the neighbourhood of the injection. Any effect produced—and we shall see that there are some of these effects—by absorption of the drug injected into the general circulation is an accidental effect not to be counted on as part of the desired analgesia. When large doses are used within the subarachnoid space, or even in the sacral canal, a mental condition approaching the unconsciousness of narcosis is sometimes obtained. Very susceptible persons, indeed, may become lethargic even from injections into the tissues or beneath the skin. Local methods, however, do not aim at these mental effects. They are designed to produce analgesia, absence of sensibility to pain, and generally the result of local injections is thus limited. The absence of sensibility to pain is often accompanied by sensibility to touch and to heat and cold and by some paralysis of motion. Even the

insensibility to pain varies, and we shall see that there may be complete insensibility to the pain of cutting a part, but lively sensation of the pain caused by dragging on the same structure. The extent to which local methods are used varies greatly according to the views and practice of operators and anæsthetists. There is little in the surgery of to-day that cannot be performed under some form or other of local anæsthesia. It does not follow that this is the best measure to employ. Much consideration must be given to the advisability or the opposite of allowing the patient to be completely conscious during operation. For this reason it is the writer's own practice whenever he uses local methods to invoke the aid of preliminary injection of narcotics. Fear, apprehension and nervousness, elements which, even if controlled at the time, may have injurious results on the patient's subsequent mental or bodily health, are in this way counteracted. Nevertheless, even with the aid of narcotics, there are many persons who are unsuitable subjects for local anæsthesia. They become faint during the process, or else the mental upset caused to them is worse than any physical disturbance that might follow a general anæsthetic. All highly nervous persons come into this class. The after-pain which often follows operations under local anæsthesia is a drawback to its use in those who are very susceptible to pain. Children cannot as a rule be handled conveniently with local anæsthetics. An exception to this rule is found in the use of spinal injection for infants and young children. This has been found of the greatest value in acute septic abdominal complaints. For operations in the treatment of congenital pyloric stenosis Farr [1] has found local anæsthesia perfectly well suited to infants. The method should be refused, unless there are serious reasons for preferring it to any form of general anæsthesia, for persons who are not suitable subjects. Such reasons do arise, but they are rare when an expert anæsthetist is available. It may be here remarked that local anæsthetics are most widely used in those countries and places where the administration of general anæsthetics has received no special study. In the great majority of instances when local methods are used for major operations the finest result attends their combination with enough of a general anæsthetic to produce unconsciousness. It is a very rare occurrence that even this amount of general anæsthetic, provided, for example, by " gas and oxygen," or scanty supplies of C.E. mixture, is contra-indicated. Amputations for diabetic gangrene, where the disease is in an advanced stage, operations upon the subjects of active phthisis, or upon those in whom there is other acute and extensive disease within the chest,

[1] *Journal American Med. Assoc.*, Aug. 9, 1919, p. 391.

are perhaps the most prominent examples when inhalation anæsthesia should be avoided. We have already alluded to the great advantage, through prevention of shock, which is conferred by blocking the nerves in many extensive operations. In abdominal procedures there is added to this the complete relaxation of muscles which can be obtained by local or spinal injections. When these are combined with a general anæsthetic which prevents adverse mental effects and is not followed by sickness or other ill consequences anæsthesia attains its highest success. Broadly speaking, we may say that the **special field for purely local analgesia is provided by operations on superficial parts.** Here it is most easy of application and most certain of success. A good example is provided by the operation for strangulated hernia, which, when the patient's general state is already serious, is best performed under local anæsthetics. The removal of superficial tumours, the amputation of fingers and toes, tracheotomy, and operations on some thyroid tumours provide other occasions in which purely local methods are often successfully applied. Sir St. Clair Thomson has described the advantage of injecting a few drops of cocaine into the lumen of the trachea before opening it in the operation of tracheotomy.[1]

If the accessory circumstances of administration are important where general anæsthesia is concerned, they are doubly so when the patient is conscious throughout the operation. When local analgesics are employed for major surgery success depends largely on care in these accessories. The first important element is time. Deliberate action is necessary ; there must be no hurry about local analgesia, and in practice the amount of time needed often prevents its employment. Then everything must be done to secure a quiet mind to the patient, to prevent his special senses from being aroused, and to induce in him the conviction that he will feel no pain. As little talking, as little disturbance of the patient, and as little moving of instruments and dishes as possible all help. The patient should already lie on the operating table when the injections are made, in order that he may not have to be lifted afterwards. When the table is wheeled into the operating theatre a screen is put before his eyes or a thin towel laid gently over his face. If preliminary narcotics have been used, the ears should be tightly stuffed with cotton-wool. When sight and hearing are in this way dulled or obliterated other sensations too are more easily abolished, and often the patient will remain in a state of drowsy comfort throughout the operation, and at its close will ask, if spoken to, why the surgeon does not begin. For small superficial operations, of course, no such

[1] *Brit. Med. Journal*, Oct. 11, 1919, p. 460.

elaborate procedure is necessary, and unless the subject is nervous the local agent alone is sufficient. Yet even for these slight operations one preliminary injection of omnopon and scopolamine enhances the patient's comfort. The patient during local analgesia should always be recumbent and should have a pad to support the hollow of the back. From the **point of view of safety** infiltration and regional analgesia are probably less dangerous than any form of general anæsthesia. The same cannot be said of spinal injections. The actual relative danger of this and of general anæsthesia it is impossible to determine. Numerous statistics have been published of spinal injections. According to some the method is so free from risk that no death has occurred in many thousands ; according to others the mortality has been one in only a few hundred. The opinion is commonly held that, taken all round, spinal analgesia is about on a par with chloroform anæsthesia as regards risk. In both the experience and skill of the administrator are the most important determining elements of safety. The risk of spinal injection lies, besides sepsis, in the possibility of the drug used reaching and affecting the bulbar centres or of its being absorbed into the general circulation to a dangerous extent. Spinal analgesia is especially risky in those who are suffering from shock, in feeble persons with low blood pressure, and in the subjects of syphilis or any general infection. Very many operations can be equally well performed under spinal or general anæsthesia. The choice must be made for each individual, according to which method will best suit the patient and meet the requirements of the operator concerned. Spinal anæsthesia is not generally to be advised for operations above the umbilicus.

The Drugs employed for Local Analgesia: their Chemical and Physiological Properties

The history of local analgesia really begins with the discovery of cocaine in 1884. Before that time there was no local analgesia worthy of the name. Many attempts had been made from the earliest times to produce local insensibility. Compression, cold, and the local application of those drugs which were known to be capable of producing narcotic effects when taken by the mouth were the means employed. The results were inconstant and unsatisfactory. The aid of electrical currents was also invoked to heighten the effect of local applications, or by themselves to produce insensibility. The measure of success achieved by electric currents in the production of local analgesia is, however, small. The use of *cold* as a local analgesic persists to the present

day. Freezing the skin is still sometimes employed for incising small abscesses or boils and similar small superficial operations. Richardson in 1866 devised an atomizer for using ether or chloroform in a finely divided spray on the skin. This has been superseded by sprays of more rapid action, and to-day ethyl chloride released in a spray from a sealed glass tube is the best agent for freezing the skin. Held about a foot from the surface the ethyl chloride spray causes immediate freezing of the skin. Sensory nerves lose their functions as soon as the tissues round them are cooled to freezing point. Thus a terminal anæsthesia is produced by freezing the skin. With the subsequent thawing of the tissues sensation rapidly returns. In inflamed parts there is pain both at the freezing and at the thawing. The skin becomes hard and white, through the formation of ice in the tissues (Braun). The sense of touch and pressure may persist, so that the patient knows when the knife is inserted, but does not feel it as pain. In using the spray care must be taken to stop it as soon as the superficial layers are frozen. Attempts to obtain a deeper anæsthesia result in permanent injury to the tissues.

Tumefaction anæsthesia by the injection of water or weak salt solution has been used, but is unsatisfactory. The pain produced by the tumefaction is equal to that which it prevents from the operation. If the tumefaction is reduced, and with it the pain of the injection, then the anæsthesia is imperfect.

The *requirements demanded of local anæsthetics* [1] are these :—

(1) The substance must be less toxic than cocaine in proportion to its local anæsthetic power.

(2) The agent must not cause the slightest irritation or tissue injury, but must be absorbed from the place of application without any secondary effects.

(3) The agent must be soluble in water and its solutions stable and capable of sterilizing by boiling.

(4) It must be possible to combine the agent with suprarenin (adrenalin).

(5) For particular places of application, as, for instance, mucous membranes, the anæsthetic must be able to penetrate rapidly.

Novocaine and alypin have made the use of cocaine in surgery almost obsolete. Eucaine has been superseded by novocaine, and tropacocaine and stovaine are almost entirely confined to lumbar anæsthesia.

Cocaine, although superseded for injection purposes, is still used as an anæsthetic application for the eye, the nose, the

[1] Braun's "Local Anæsthesia," 1914, p. 129.

pharynx, larynx, and urethra. As the prototype of local anæsthetics it deserves full consideration. It has lost its place in practice because of its powerful poisoning qualities. Although cocaine poisoning can be restrained by using sufficiently dilute solutions, so that the dose necessary to produce symptoms is not at one time absorbed into the circulation, yet even with this precaution some persons are not safe. Some people are peculiarly susceptible, as we have seen is probably true of chloroform. Moreover, there is no true antidote to cocaine.

Cocaine is one of four alkaloids obtained from the dried leaves of the coca plant. It is now also prepared synthetically. In Peru some of its peculiar properties have for centuries been known to the inhabitants, who chewed leaves of the plant to gain mental calm and physical endurance and to alleviate hunger. Braun states that during the reign of the Incas only the royal families had the right to cultivate the coca plant and enjoy its consumption.

Cocaine, $C_{17}H_{21}NO_4$, is only slightly soluble in water, but readily so in alcohol, ether, and ethyl chloride. It combines readily with acids, and the salt formed by its combination with hydrochloric acid (hydrochloride of cocaine) is the form commonly used and known as cocaine. This is a white crystalline powder readily dissolved by alcohol or by water and having a bitter taste. Cocaine solutions cannot be sterilized by boiling. They lose their power. Other salts of cocaine are used in dental surgery, and the lactate has been used especially for allaying vesical pain.[1] Cocaine has no anæsthetic action on the unbroken skin. Koller in 1884 demonstrated the fact that a 2 per cent. solution instilled into the conjunctival sac made the eye insensitive enough for operations to be performed on it without giving pain. Soon its application was extended to the nose, larynx, and urethra, and by injection into the tissues local anæsthesia was obtained for general and for dental surgery. Cocaine is a protoplasmic poison, and it was not long before mild, severe, and fatal symptoms were evoked by the injection of the drug or even on its application to mucous membranes. Symptoms due to cocaine may be local or general.

Locally cocaine paralyses sensory and motor nerves, muscle fibre both smooth and striped, and the muscle of the heart. It causes contraction of the small capillaries and arteries and paralysis of the leucocytes. Its anæsthetic effects are independent of its power to produce local anæmia. The local slowing of circulation, however, causes the absorption of cocaine to take place slowly and so intensifies the local effect. This result is obtained with other local anæsthetics by adding adrenalin. Touch and pressure

[1] Hewitt, *loc. cit.*, p. 510.

sense are less sensitive to the action of cocaine than the sense of pain. The intensity and extent of anæsthesia produced by injecting solutions of cocaine depends on their concentration. With weak solutions, under 1 per cent. for instance, anæsthesia is limited to the area actually injected. Temperature sense is most easily abolished, then sense of pain, and then sense of touch and pressure.

Dropped into *the eye* solutions of cocaine cause anæsthesia of the conjunctiva, cornea, and iris. The pupil is widely dilated and accommodation paralysed. Injected into the tissues or into nerves it causes paralysis of sensory and motor fibres, though the latter require more cocaine than the former. In the subdural space it produces paralysis of sensation and of movement in all the parts innervated by nerves arising below the point of injection.

General symptoms from cocaine are in human beings mostly due to its action on the central nervous system. The cerebral cortex is most sensitive to its action, then the medulla oblongata and cord. Excitement and elated feelings with loquacity are caused by mild doses, while stronger ones cause hallucinations, convulsions, paralyses, and coma. The *heart's action* is depressed, the beat becoming weak and irregular. Faintness is readily produced in some persons by very small amounts of the drug. Great breathlessness is caused by the absorption of large doses, and death, if it ensues, is attributed to tetanic contraction of the diaphragm. The mildest form of cocaine poisoning is shown by sudden but transient giddiness. In severe cases there is unconsciousness with cold sweating extremities and great feebleness. Vomiting is a frequent symptom. The most dangerous form generally begins with epileptiform convulsions, followed by loss of sensation and paralysis. Deep coma leads to death, which Braun attributes to paralysis of the respiratory centre.[1] This author points out that the occurrence and intensity of cocaine poisoning do not depend only on the quantity given, but also on the time during which it is administered. Introduced into the blood suddenly—that is to say, in concentrated solution—death may be caused by an amount which could be given with safety if spread over some time in a dilute solution. Experiments showed that a 5 to 10 per cent. solution containing 0·1 gr. of cocaine was fatal to rabbits, whereas the same amount given in a 1 per cent. solution caused mild symptoms only or none at all.

Poisoning very rarely accompanies the use of cocaine in the eye. It has occurred fairly often after applications to the mucous membrane of the nose, but not with fatal results. These, however,

[1] Braun, *loc. cit.*, p. 86.

have followed its use on the fauces, the larynx, and the mucous membranes of the urethra and of the bladder, as well as after subcutaneous injections. When large absorbent surfaces—for example, the interior of the bladder, the sac of a hydrocele, joint cavities, or the mucous membrane of the male urethra—are exposed to solutions of cocaine these should not be more than 0·1 to 0·2 per cent. For injection into tissues the solutions should never reach 1 per cent. in strength. Stronger solutions, of course, are admissible for mere limited application to mucous membranes, and in nose and throat work 5 to 10 per cent. is a strength commonly employed. In the eye drops of a 4 per cent. solution are usual. When strong solutions are brushed on the naso-pharynx care must be taken that there is no excess which might be swallowed. The urethra seems peculiarly susceptible to the action of cocaine. Small quantities of even dilute solution when injected into the urethra have produced toxic symptoms. To combat the symptoms of cocaine poisoning the head is to be lowered and amyl nitrite offered for inhalation. Ether inhalation may be used for controlling convulsions. Stimulants may be needed for increasing the heart's action and artificial respiration for combating the onset of respiratory paralysis.

Cocaine is disintegrated in the body. According to Braun, it enters into chemical combination with protoplasm and is not taken up into the circulation as cocaine. He says that in the excreta and organs of animals poisoned by cocaine little or no cocaine can be found.

Tropacocaine is, like cocaine, a vegetable alkaloid, and was originally obtained from the leaves of the Java coca plant. It has since 1892 been synthetically prepared, the salt of the hydro chloride being the preparation commonly employed. The action of tropacocaine is much weaker than that of cocaine, more being required to produce local anæsthesia and the insensibility lasting much less time. It is rarely used except for spinal injections, and for these it is by most anæsthetists regarded with less favour than stovaine or novocaine.

Novocaine is the best all-round local anæsthetic at present available. It is almost free from poisonous properties, either local or general, unless used in very strong solution (10 per cent. or more). Large quantities of solutions of 1 per cent. and under can be injected into tissues without damaging them and without producing general symptoms. Solutions of 2 per cent. can be used freely in the sacral canal if the injection is made slowly. Braun relates poisonous symptoms from the injection of 20 to 25 c.c. of a 2 per cent. solution into the sacral canal. The effects produced were nausea, sweating, rapid pulse and breathing,

anæmia of the face, and vomiting. Much larger quantities of 2 per cent. solution have been introduced slowly into the sacral canal without producing any undesirable symptoms. In my own experience 180 c.c. have been used in this manner with no resulting symptoms except an excellent analgesia which extended upwards as far as the skin of the face. The original drawback to novocaine was the short duration of the anæsthesia which it produced. The combination with it of *adrenalin* has overcome this defect. For ordinary infiltration and conduction anæsthesia a solution of the strength between ½ and 1 per cent. is used. Adrenalin (1 in 1,000) is added drop by drop, 16 drops to 60 c.c. of novocaine solution being used. The most generally useful way to obtain a correct solution is by dissolving the prepared tablets of novocaine with suprarenin. It is important that the concentration of the adrenalin should be very weak, and the local ischæmia which it produces follows the use of solutions as weak as 1 to 200,000. Adrenalin, if injected in too strong solution, easily causes a feeling of oppression at the chest and palpitation. The face looks worried and pale. Great danger attends the injection of adrenalin when the patient is *lightly under chloroform.* Consequently when, as often happens in nasal surgery, the use of adrenalin is to be combined with general anæsthetics the local injection is made before the anæsthetic administration begins. Mere application to the mucous membrane of the nose of swabs soaked in adrenalin solution can be safely practised on the patient under chloroform. In animals injection of adrenalin has caused paralysis of the extremities with tonic and clonic convulsions, œdema of the lungs and glycosuria. The concentration of adrenalin should never be enough to cause complete cessation of bleeding. Medium-sized arteries should be able to bleed, otherwise there is grave risk of secondary hæmorrhage. The work of Braun has placed the use of adrenalin in combination with novocaine on a sound footing, has greatly extended the scope of local anæsthesia, and has increased its safety. Intravenous injection of adrenalin is stated to be forty times more dangerous than subcutaneous injection, and when poisonous symptoms have followed the use of a weak solution it has been held that the injection happened to be made directly into some small vein. Adrenalin is prepared both in a crystalline form and as a solution of 1 in 1,000. Suprarenin, epirenin, and tonogen are other names under which the same body is sold. As a powder it is white or slightly red. Solutions in water soon go red or brown owing to oxidation. In the presence of some hydrochloric acid the solution remains clear and colourless and can be boiled without hurt. Adrenalin is very sensitive to the action of alkalies, a point to be carefully borne in mind when

solutions are boiled for sterilizing purposes, as soda is commonly used on these occasions unless specially countermanded.

Hydrochloride of quinine and urea has been praised as a local anæsthetic because of the long duration of the insensibility which it causes. It has been much used for deep injection in abdominal cases in order to prevent after-pains. Some observers, however, believe that it causes damage to tissue, and it has been held responsible for the later extrusion of sutures. The strength for injection is up to 1 per cent.

Stovaine, like novocaine, alypin, eucaine, and the orthoform group of local anæsthetics, was synthetically prepared after Einhorn's discovery of the chemical composition of cocaine (Braun). Stovaine belongs to the amido alcohols. It is a glistening white crystalline powder readily soluble in water and can be sterilized by boiling. According to Braun, even in 1 per cent. solution, stovaine damages tissues. It should never be used, therefore, for local, but only for intra-spinal, injections.

Alypin is similar to stovaine. It easily produces pain if injected subcutaneously, and should not be used in this way. In strong solutions both alypin and stovaine have destructive action on nerve tissue. It has been used with success in ophthalmic and nose, throat and ear work, and for spinal anæsthesia, the strength of the solutions used being the same as those of cocaine.

Eucaine is a synthetically prepared alkaloid similar in chemical construction and physiological action to cocaine. When injected, however, it causes, besides anæsthesia, severe irritation and hyperæmia, and is consequently ill suited for local anæsthesia. Eucaine is, in fact, rarely used, its place being taken by *β-eucaine*, another alkaloid, the hydrochloric salt of which is very soluble in water. This salt is for convenience spoken of as β-eucaine. The local anæsthetic properties of solutions of β-eucaine are like those of slightly less concentrated cocaine solutions. Like cocaine, too, it readily produces toxic symptoms. Braun states that the only recorded cases of poisoning from β-eucaine followed lumbar injection. If used for local anæsthesia it must be treated with the same circumspection as cocaine. Its use is commonly restricted to the eye, nose, and throat. β-eucaine can be sterilized by boiling.

Holocaine is an amido compound made by combining phenacetin and phenatidin. It can be sterilized by boiling, but it appears to be inferior to and more toxic than novocaine as a local anæsthetic.

Orthoform is a white powder only slightly soluble in water which exerts its anæsthetic properties only when in contact with

exposed nerve ends. Being insoluble in the body fluids, it produces a long-lasting anæsthesia at the place of application. On the other hand, it is useless on mucous membrane or the unbroken skin. It has been largely used for the relief of local pain after tooth extraction, on burned or wounded surfaces, etc. Vertigo and vomiting have attended its use.

Nirvanin is a substance made by Einhorn and Heinze in attempting to increase the solubility and lessen the irritating properties of orthoform. It is not suitable for eyework, but can produce local anæsthesia by injection in strengths of ·25 to 1 per cent. It can produce toxic symptoms, excitement followed by paralysis, in like fashion to cocaine and the other allied anæsthetics, over which it offers no advantage.

Anæsthesin and subcutin are other orthoform products. These, as well as *propæsin* and *zykloform,* are sometimes used in the dressing of wounds, but rarely as injection anæsthetics.

Aneson, or *anesin,* is an obsolete local anæsthetic that had some vogue towards the end of the nineteenth century.

We may sum up the position of the local anæsthetics in practice by saying that **novocaine** is the agent of choice for all forms of injection, except the intra-thecal, when **stovaine** is to be preferred. **Cocaine** is much used for the eye, nose, pharynx, and larynx, although **β-eucaine** is chosen by many. **Tropacocaine** may be employed for intra-thecal injection.

Surface, Infiltration, and Conduction Anæsthesia

In the surgery of the eye, the nose, and the throat local anæsthetics are generally applied by the operator himself. Drops are instilled into the conjunctival sac, while tampons soaked in the anæsthetic solution are applied to the mucous membrane of the nose. Some operators inject beneath the mucous membrane. The pharynx and the larynx are either brushed or sprayed with the anæsthetic. Stronger solutions are needed for these surface applications than when the drugs are injected. Similarly infiltration and conduction anæsthesia is commonly procured by the operator himself. Some surgeons, however, prefer to leave this to the anæsthetist, and in any case he should be familiar with the method, because he will frequently give a general anæsthetic in association with local anæsthesia, and will not, unless he is thoroughly acquainted with its effects, be enabled to give the patient the full benefit of the combined method.

Infiltration anæsthesia, as demonstrated by Reclus and by Schleich, the two men who did most to introduce and perfect the method, consisted in saturating the tissues with the anæsthetic

solution layer by layer. The anæsthesia is begun by an endermic injection, which raises a wheal in the skin itself. At the edge of this wheal another injection is made, and so on until the whole line of the proposed incision is œdematous with the injected fluid. This anæsthetic line being incised, the deeper structures as they are reached are injected with the anæsthetic fluid. Schleich used three different solutions of cocaine. His No. 2 solution was used in 95 per cent. of all cases. It consisted of :

Cocain muriat., 0·1 ;
Sod. chlor., 0·2 ;
Morphin. hydrochlor., 0·02 ;
Hyd. dest., 100.

There is no reason nowadays to use cocaine at all, and if Schleich's method is carried out it should be with novocaine and adrenalin in solution of less than 1 per cent. Braun showed that the sensory nerves of the skin and fasciæ in many parts of the body run in the subcutaneous tissue, and that by infiltrating this these structures are rendered insensitive. Injections into the skin itself are, therefore, not needed except to the small extent necessary to enable the needle to be pushed painlessly into the subcutaneous tissue. With one or two small anæsthetic spots in the skin a long needle can be entered in various directions and render insensitive wide areas of skin, fascia, and deeper structures, according to the direction and depth to which the needle is pushed. The solution is forced in slowly and continuously while the needle is entered and while it is withdrawn from the deepest part to which it is sent. This method of tissue infiltration is generally used in practice and combined with conduction anæsthesia when deep structures are involved. *Conduction* or *regional anæsthesia* depends on affecting nerve trunks themselves with the anæsthetic solution and so rendering anæsthetic the areas which they supply. No attempt is made to send the solution into the nerve itself or even into its sheath. The anæsthetist seeks to inject the tissues around the nerve at some point where it can be easily and certainly reached and where it is not near a large vessel. A considerable time, about twenty minutes, has to be allowed for blocking a nerve. Regional anæsthesia has the advantage that it can be used, if there is a nerve suitably to hand, for rendering insensitive septic areas on which operation is needed and into which it would be unsafe to make direct injections. In the case of infected, inflamed teeth, for instance, the nerve may be blocked at a distance for the tooth extraction, though an injection in the immediate neighbourhood of the tooth would be dangerous. Similarly whitlows, abscesses and boils can often be conveniently

treated by regional anæsthesia. Braun has pointed out that in order to affect nerve trunks the injected solution must diffuse through the connective tissue layers surrounding the trunks before the nerve substance is rendered anæsthetic. Therefore sensory nerve tracts are more readily interrupted when the injection is made in an area where their branches are fine rather than near the beginning of the nerve trunk. For not only does the nerve trunk increase in thickness towards its proximal end, but its connective tissue covering also increases. In the spinal canal the nerve trunks have no connective tissue covering. Consequently spinal anæsthesia develops very quickly after injection. Sacral anæsthesia, on the other hand, takes time because the solution attacks the nerves near their roots, outside the dura, but protected by extensions of this covering. Infiltration of connective tissue layers containing nerve tracts produces at once infiltration anæsthesia in the area injected and conduction anæsthesia in the area of distribution of those tracts. Thus commonly local anæsthesia, even when the neighbourhood of nerve trunks is not expressly sought, is a combination of infiltration and conduction methods.

Material and technique.—The solution used must be sterile and isotonic. The ½ per cent. novocaine solution is commonly employed. It is made as follows:

Novocaine, 0·50 grm.;
Sodium chloride, 0·82 grm.;
Distilled water to 100 c.c.

Outside institutions the most convenient method is to use the prepared tabloids dissolved in normal saline and boiled. The synthetic suprarenin that the tabloids contain can be boiled without damage. If the boiling is done in a conveniently small porcelain basin the solution, when cool, can be drawn straight from this into the syringe. By boiling in only a small amount of saline and then adding more till the proper concentration is reached the cooling takes but little time. The "Record" syringe and Gray's syringe have proved perfectly satisfactory instruments (Figs. 45, 46). The former has the disadvantage that there is no provision for making counter-pressure. Gray's syringe is preferable, therefore, whenever deep injections are made.

Needles and syringes are to be boiled before use in plain water. After use syringes are boiled again, thoroughly dried, and a drop of castor oil is put inside to prevent sticking of the piston. The needles, after use, are sterilized and threaded with a fine wire to keep them pervious. Robert Farr [1] has for years used a pneumatic

[1] *Jour. American Medicine Association,* Aug. 9, 1919, p. 391.

injector for the performance of infiltration. This instrument does away with the necessity for repeatedly filling a syringe or for having a number of syringes handy when an extensive amount of infiltration is necessary.

Mr. E. G. Slesinger[1] has designed a pneumatic injector for local anæsthesia, to which any type of needle can be fitted by a bayonet-catch connection. The instrument consists of a glass container in a metal frame with a graduated scale. Into this cylinder are screwed at top and bottom caps lined with composition material making an airtight chamber. In the top cap are a screw plug for filling and a tube fitted with a tap,

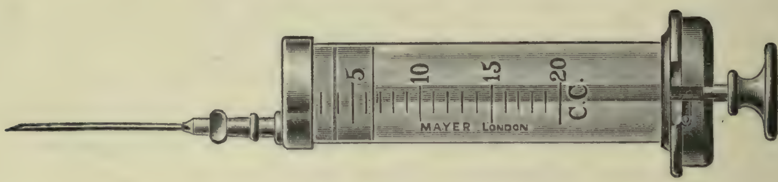


FIG. 45.

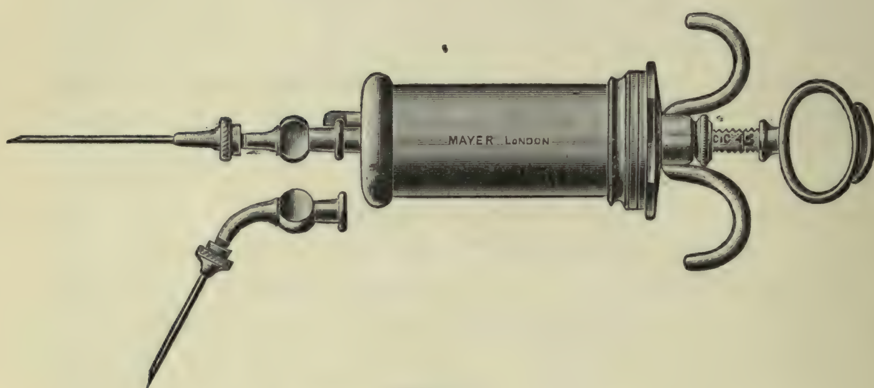


FIG. 46.

in the end of which is a Dunlop bicycle valve. The bottom cap has an exit tube with tap. From this tube, connected by a bayonet-catch, runs a flexible metal tube, to the other end of which the injection valve is attached by another bayonet-catch. This valve is so constructed that, when at rest, no fluid can pass it. Light pressure on the button with which it is provided allows a free flow to be established : 100 c.c. being poured in from above, the apparatus is pumped up with a bicycle pump attached to the valve in the top cap. When no further pumping is possible the pump is removed, the tap on the upper valve closed, that on the bottom one opened, a needle attached, and the apparatus is ready for use.

For raising the small anæsthetic circles in the skin a fine, short needle should be used. For deeper injections a longer and stouter steel needle with very short bevel is best. These needles

[1] *Brit. Med. Journal*, Aug. 2, 1919, p. 139.

should be from 2 to 4 inches long. The finer they can be, compatibly with not breaking, the better. Needles must fit their syringes absolutely without leak. In making deep injections the needle should never be pushed in up to the hilt, in case it breaks and has to be withdrawn. Where the skin is loose and movable it is pinched up between the thumb and first finger of the left hand for injection. The needle is pushed into the skin, bevel upward, and parallel to the surface. In the scalp and places where the skin is tightly held down much pressure is needed. The points where the skin is to be entered are cleaned with iodine or with ether. Sterile towels are arranged around so that the syringe and needle and the administrator's hand and wrist, all of which have been carefully cleaned, touch nothing that might contaminate them. A certain amount of pain often accompanies the distension of tissue caused by injections beneath the skin. This pain is slight, however, and scarcely noticed when a preliminary hypodermic injection of narcotics has been made.

It is not within the scope of this work to describe in detail the injections to be made for every operation. A few typical examples are given, and the reader will realise that for every operation the principles remain the same, the details varying according to the local anatomy, particularly the nerve distribution, without a thorough knowledge of which local anæsthesia is not successfully practised. For example, it is never necessary to penetrate periosteum, since this sensitive structure is not innervated from the bone, but superficially. The pleura and peritoneum, in like manner, do not require infiltration if the connective tissue and muscles superficial to them are properly infiltrated.

Operations on the scalp, for instance the removal of a sebaceous cyst, are amenable to a local anæsthesia produced in this way. At two points, which represent the ends of the proposed incision across the tumour, a small anæsthetic lump is raised by injection of a few drops of $\frac{1}{2}$ per cent. novocaine-suprarenin solution into the scalp. This injection is made through a fine needle under firm pressure. Through these "buttons" the needle is then thrust vertically into the subfascial layer and injections are made in two directions from each point of entry. The infiltrated lines then form a rhombus within which lies the tumour. Within this rhombus all structures down to the bone are anæsthetic.

Superficial tumours involving the skin in any part of the body are treated in a similar way. The tumour itself is not touched by the needle. Its base is circuminjected by injections into the subcutaneous tissue. For the removal of tumours not very deep but beneath the skin *thyroid adenoma* serves as a good example. An anæsthetic button is raised at three points in the skin, repre-

senting each end and the middle of the proposed incision. This is done with a small syringe and fine needle, the end of which, bevel upwards, is plunged into the skin itself. Then a long needle, attached to a syringe holding at least 10 c.c. of the $\frac{1}{2}$ or 1 per cent. novocaine-adrenalin solution, is pushed through each of the little white anæsthetic circles in succession. It is thrust along almost parallel to the line of the proposed skin incision, injecting as it goes, till its point is in the muscle layers overlying the tumour, this layer as well as the subfascial and subcutaneous layers of tissue being well infiltrated. As the needle is withdrawn the solution continues to be injected into the layers of tissue traversed. These deep injections sometimes cause a sensation of heat. When the tumour is large as much as 100 c.c. of the solution may be needed; five or six points of injection may be necessary instead of three. The injections should surround the tumour. The anæsthesia extends laterally well beyond the line of incision, and thus the manipulations necessary to dislodge the tumour, unless this is particularly adherent, may be quite free from pain. Often during the deeper parts of the operation, unless the adenoma is very movable, a short period of general anæsthesia is required. In other situations than the neck, if the tumour can be raised, injections should be made to involve the structures beneath as well as those around the mass to be removed.

For *tracheotomy* the line of incision is infiltrated subcutaneously through one puncture. If, however, there is no hurry about the operation and the neck is fat, it is better to make an anæsthetic button on each side of the trachea at the level of the middle of the proposed incision. From these two points the field of operation is rendered anæsthetic by subcutaneous and deeper infiltration upwards and downwards.

For *resecting a rib* four points of injection are employed, two over the intercostal space above and two over that below the rib. The points are so chosen that when injection is made through them the portion of rib to be resected lies entirely within the area rendered insensitive. After raising the skin buttons the needle is pushed in vertically to the skin and injection is made between and into the intercostal muscles. When this is done, the needle is withdrawn, but not completely, and is then directed so as to inject the soft tissues overlying the rib itself and the rib above and below it. About 40 c.c. are needed for resecting one rib. When several ribs have to be resected it is best to secure a good conduction anæsthesia by injecting near the intercostal nerves as well as to infiltrate subcutaneously the line of incision. In order to inject the nerves the ribs are marked out, including the

one above and the one below those to be resected. The needle is first introduced so as to hit the top rib marked out, just to the outer side of the erector spinal muscle, and when the point of the needle touches the rib it is withdrawn slightly and lowered. If then pushed on it should encounter the subcostal groove in which the intercostal nerve runs, and 5 c.c. are there injected. The same manœuvre is carried out in turn for each of the ribs below that which has been marked. Finally the subcutaneous tissue is infiltrated along the line of incision and for an inch or so on each side of it. Persons suffering from empyema are often especially suitable subjects for local anæsthesia, inasmuch as general anæsthesia involves an exaggerated risk. When the general condition is poor and the lung on the other side seriously affected inhalation anæsthetics are more than usually dangerous. W. Meyer,[1] regarding intra-thoracic surgery generally, pleads for "more frequent and persistent use of local and regional anæsthesia during the entire operation in order to avoid aspiration of intra-bronchial contents into the lung tissue proper, which often occurs during general anæsthesia."

For the operation of *thoracoplasty*, when extensive removal of ribs is carried out to allow expansion of the fibroid lung, local anæsthesia is usually essential. Numerous para-vertebral injections are required, and the process is a trying one both to anæsthetist and to patient. It is difficult to avoid pain at the deep surface of the periosteum and great shock may attend the operation. Braun recommends that the injections to block the nerves should be made, not close to the spine, but at the lateral border of the erector spinal muscle, about 5 cm. from the middle line. Subcutaneous infiltration may first be made of the whole line on which the points of injection will lie for the nerve blocking.

Amputations of digits, fingers or toes, require subcutaneous infiltration at the base of the proximal phalanx of the digit concerned. The digital nerves are involved in a ring of infiltrated tissue, and the whole digit distal to the injection becomes insensitive. The needle is entered at two points, on the dorsal surface of the interdigital fold on each side of the digit to be amputated. The solution is from here injected towards the palm and across the dorsal aspect of the base of the digit. For the thumb and little finger, and the corresponding toes, one of the points of injection is on the outer and inner side respectively of the hand or foot.

When injecting to affect *nerve trunks* which can be located from the surface—the brachial plexus, for example—the anæsthetist must bear in mind the proximity of large vessels. Accordingly

[1] *Medical Record*, April 9, 1921.

in these regions he must insert the needle first unattached to the syringe. If no blood escapes he is then at liberty to inject his solution, knowing that no large vessel has been tapped. It is especially for operations on the limbs, generally amputation, that infiltration of large nerves is required. The anæsthetist has to rely on an accurate knowledge of the anatomy of the part. After a subcutaneous circuminjection of the area which will be involved in the incision, he makes sure of an effective anæsthesia by deep injections in the immediate neighbourhood of the large nerves. In the upper limb the musculo-spiral, the median, the ulnar, the radial, internal cutaneous and musculo-cutaneous nerves can be reached, and in the lower limb the sciatic, anterior crural, external popliteal, and posterior and anterior tibial nerves. The process of cutting down under local anæsthesia upon a nerve trunk in order to inject it is rarely required of the anæsthetist. When general anæsthesia is not employed for amputations of the lower limb the spinal is more often used than the regional method. The latter, however, has sometimes especial advantages as regards the patient's general condition. In advanced diabetes, for example, if an amputation for gangrene is required there may be good reason to avoid an intra-spinal injection. On the other hand, in many amputations of the lower limb the local conditions, bruising, laceration, etc., preclude any form of local injection, and a spinal has to be selected if no general anæsthetic is to be used.

The operations for *hernia* are usually very amenable to local anæsthesia. Unless the hernia is very large or complicated by firm adhesions, the method finds in these operations one of its most suitable fields. When used for *inguinal hernia* local anæsthesia is directed to paralysing the ilioinguinal iliohypogastric, and external spermatic nerves. Two skin punctures are necessary. The first is made about 1½ inches internal to the anterior superior spine of the ilium. The needle is pushed in at right angles to the surface, piercing the aponeurosis of the external oblique muscle and muscle fibres of the internal oblique and transversalis, solution being injected on the way in and on the way out. The needle is then reinserted more obliquely towards the ilium and pushed on till it strikes thin bone, injections being made continuously again while it enters and leaves. A third injection is made from the same puncture downwards towards the pubic symphisis. This injection should reach below the aponeurosis of the external oblique. The second puncture is made at the external inguinal ring. From this point an injection is made along the inguinal canal. From both the punctures subcutaneous infiltrations are made at each side of the line of

incision. When the hernia is irreducible, subcutaneous infiltration of the scrotum is also needed. For *umbilical* hernia the abdominal wall is infiltrated around the swelling from three or four points, the injections being carried as deeply as the subperitoneal part.

Anæsthesia of the *abdominal wall* can be well secured by local injection, and for such an operation as gastrostomy, where little or no manipulation inside the abdomen is needed, the method acts well. When retraction of the walls has to be employed, or when viscera have to be pulled upon, some general anæsthetic generally becomes necessary. To render the epigastrium anæsthetic two punctures are needed, the higher close to the left side of the apex of the costal arch and the lower at the lowest point of the proposed incision. The needle is pushed in vertically to the surface till it almost reaches the peritoneum. It is drawn out again, but not entirely, and then pushed in more and more obliquely downwards two or three times, according to the thickness of the wall, injections being made always both on the way in and on the way out. The same proceeding is carried out from the lower puncture, the point of the needle being directed more and more in an upward direction.

Pressure anæsthesia and *venous and arterial anæsthesia* have now only an academic interest. The former method, whereby loss of sensibility was procured by firm and long pressure on a nerve, was dangerous and uncertain, for sometimes the motor paralysis procured was permanent. The old idea that the effect of pressure was due to interruption of the blood supply was incorrect. Unless the nerves themselves are paralysed by pressure it is inefficient as an anæsthetic.

By *injecting into an artery or vein* and interrupting the circulation through it terminal and conduction anæsthesia are produced. The method, however, is in no respect so good as infiltration and conduction anæsthesia without penetrating vessels.

Local anæsthesia in dental surgery is widely employed, but here again the anæsthetist is rarely called upon to make the injections. The rule that septic tissue must not receive injection has to be scrupulously observed within the mouth. Regional anæsthesia can often be used for a septic tooth, the injection being made into healthy mucous membrane. The complete insensibility during which a tooth is extracted under local anæsthesia has sometimes a disappointing sequel in severe after-pain. It is wise, therefore, to limit the method to those who are not highly susceptible to pain or are not greatly upset by its occurrence. A large proportion of the accidents which have attended the use of local anæsthetics have occurred owing to the ignorant employment of cocaine or of unclean instruments in the mouth. Local

necrosis or the constitutional symptoms of cocaine poisoning, in some cases ending fatally, have been the consequences. For rendering extractions painless a 2 per cent. novocaine-adrenalin solution is used. When one tooth is to be extracted from the upper jaw the injection may be made locally, beneath the mucous membrane at the root of the tooth. The needle is inserted horizontally into the fold of mucous membrane above the roots of the teeth, a point being chosen over the tooth in front of that to be extracted, and from here the needle is pushed along to a corresponding point over the tooth behind the one to come out. A second injection is made on the lingual surface, the needle being pushed into the mucous membrane covering the hard palate above the root of the tooth concerned. By applying a pledget

FIG. 47.

of cotton-wool soaked in 10 per cent. novocaine solution to the gum for some minutes before the injection the prick of the needle can be rendered painless. When conduction anæsthesia is wanted, it is secured by making injections under the mucous membrane covering the maxillary tubercle. The *lower teeth* can be extracted painlessly after submucous injection about their roots made from the labial surface. For the molar and premolars, since the bone here is thick, regional anæsthesia is often chosen, the inferior dental and lingual nerves being blocked. Injections into the gums are to be made slowly. Usually slight blanching shows that they have taken effect. Generally a single tooth requires about 20 drops of a 2 per cent. solution. Firm pressure is needed, and the syringe used must be strong and provide for counter-pressure (Fig. 47).

Splanchnic anæsthesia is the variety of regional anæsthesia produced by making deep injections into the solar plexus or its neighbourhood. Since 1911, when Laewen published his cases of paravertebral conduction anæsthesia, attempts have been made to improve the results of regional anæsthesia for abdominal operations. Paralysing the spinal nerves alone did not give

entirely satisfactory results. Splanchnic anæsthesia, by paralysing the sympathetic, is stated to be more successful. Two methods have been practised. In one the abdominal wall is made insensitive by infiltration and the needle then inserted deeply through the left lobe of liver and gastrohepatic omentum, reaching the vicinity of the solar plexus. More safely this anterior method was practised by opening the abdomen under local anæsthesia and then injecting directly into the solar plexus. The second method depends upon a posterior route. Naegeli, Kappis and Labat have been the chief exponents of this measure, and the present account is from the writings of the last named. Labat [1] selected a posterior route as the best means of anæsthetising the upper part of the abdominal cavity because he attributed pain in gastric operations to traction on the parietal peritoneum, resulting in the cleavage of retro-peritoneal tissue. He uses 1 per cent. novocaine-adrenalin solution. Firstly the upper abdominal wall is rendered insensitive through five anæsthetic wheals. These are placed at the tip of the xiphisternum, one on each side at the level of the tenth costal cartilage where the external border of the rectus crosses the costal margin, and two lower ones, one on each side of the external border of the rectus a little above the umbilicus. For the splanchnic injection the patient lies on his side with the back arched. On the lower border of the twelfth rib, 7 cm. from the middle line of the back, an anæsthetic wheal is raised. Through this a needle 12 cm. long is introduced vertically to the table. It is pushed obliquely forward to strike the body of the first lumbar vertebra behind the splanchnic nerves where these join the semilunar ganglion. When the needle, introduced for about 9 cm., has struck the bone it is drawn back until its point lies in the subcutaneous tissue and reintroduced at a smaller angle. It should then pass tangentially to the body of the vertebra. When it is felt to glide along the surface of the vertebra it is pushed in 1 cm. further. At this level, if no blood escapes, 25 to 35 c.c. of the solution are injected. The injection is then repeated on the other side.

Billet and Laborde [2] have found that the deep injection on one side is enough if 50 c.c. of the solution are sent in. Their paper should be consulted by the reader interested in splanchnic analgesia, for it gives a good account of the anatomy concerned.

[1] *British Journal of Surgery*, January, 1921, p. 278.
[2] *La Presse Medicale*, April 2, 1921.

CHAPTER XXII

SPINAL ANALGESIA AND SACRAL ANALGESIA

Intra-thecal Injection—Lumbar Analgesia—Epidural Injection

To the experimental and clinical work of Corning (1885), to Quincke's lumbar puncture (1891), and to the surgical application by Bier [1] and Tuffier [2] (1889) of knowledge so gained we are mainly indebted for our present method of producing analgesia by injection of anæsthetic solutions into the cerebro-spinal fluid—intra-thecal spinal injection. In Great Britain Barker, McGavin and Leedham-Green did much to bring the method into favour, and the first named increased our knowledge of the actual disposition of the injected fluids and of their subsequent elimination. Tyrrell Gray has shown that the process is quite applicable to young children, and that in these subjects operations for acute septic abdominal conditions give better results than with general anæsthetics. The earlier experiences, as in the case of infiltration analgesia, were acquired with cocaine, and served to demonstrate the dangers of this drug. Nevertheless, even to-day there are some—*e.g.*, Delmas [3]—who maintain that, properly diluted and used according to particular directions, this is the best anæsthetic for intra-thecal injection. Bainbridge in America has had a large and successful experience with cocaine. The great majority of workers, however, prefer stovaine, novocaine, or tropococaine, the two former being most widely employed. Novocaine is generally held to be less effective than stovaine in procuring complete muscular relaxation. Morton [4] as long ago as 1901 showed that analgesia from intra-thecal injection could be made to affect all parts of the body, including the head and face. Later Jonnesco [5] has maintained that with the addition of strychnine to the anæsthetic solution this can be systematically used for producing anæsthesia for all operations on any part of the body. It must be admitted, however, that those who have imitated Jonnesco are not so satisfied as its originator with the results of his method.

[1] *Deut. Zeit. f. Chir.* (Leipzig, 1899), p. 361.
[2] *Semaine Médicale*, 1899, p. 389.
[3] *La Presse Médicale*, Aug. 28, 1920, p. 597.
[4] *American Medicine*, Aug. 3, 1901.
[5] *Brit. Med. Journal*, Nov. 13, 1909, and *Amer. Journal Surg.*, 1910, pp. 29, 33.

The majority of workers prefer to limit the use of spinal analgesia to operations below the level of the umbilicus. There is no doubt about the height to which the injected fluid can be made to reach. Experimentally coloured fluid injected into the subarachnoid space in the lumbar region has been found in the lateral ventricles of the brain. Clinically it is familiar that cranial nerves may be affected by solutions so injected, and the somnolence and unconsciousness that sometimes supervene after spinal injections may be evidence of the effect of the anæsthetic liquid on the brain itself. The height to which the injected solution travels depends partly on the pressure under which it is sent in. It depends also on the nature, particularly the specific gravity, of the solution and also on the extent to which cerebro-spinal fluid is allowed to escape before the anæsthetic solution is injected. The greater the dose of solution that is injected the longer does the resulting analgesia last, and the more cerebro-spinal fluid that is allowed to escape the higher does the analgesia extend.[1] Also, the greater the pressure with which the solution is injected the higher is the analgesia and the more quickly is it obtained. The injected fluid travels in the cerebro-spinal fluid mainly by diffusion. Consequently, as Barker showed, its effect can best be localized if it is used in a comparatively non-diffusible form. Moreover, if it is made of a specific gravity higher than that of the cerebro-spinal fluid, its position can also be influenced by gravity. For these reasons Barker added glucose to stovaine, and his mixture is widely and successfully employed. One of the most important recent improvements in the use of spinal injections depends on the demonstration of the fact that, whether a diffusible or a poorly diffusible solution is used, its position in the cerebro-spinal fluid is fixed within a few minutes of its introduction. Consequently the patient can be placed in the Trendelenburg position without fear of the anæsthetic solution dangerously affecting the vital centres in the medulla oblongata. Using Barker's solution, the writer has frequently employed the Trendelenburg position seven minutes after making the injection. During those seven minutes the head was kept raised above the level of the point of injection. Rood [2] has pointed out that the former practice of keeping the head and shoulders raised not only during the injection, but throughout the operation, and even in bed afterwards, increased the tendency to syncope, which is not uncommon after spinal injection. He states also that he has never found it possible to extend the height of the anæsthesia by elevating the pelvis after about five minutes. Employing the Trendelenburg position

[1] *La Presse Médicale*, April 20, 1921, p. 317.
[2] *Proc. Royal Soc. Med.* (Anæsthetic Section), March, 1919.

helps to counteract the tendency to and to diminish the undesirable results of the lowering of blood pressure which is always associated with intra-spinal injection of anæsthetic solutions. Spinal injections produce their effects by paralysing the nerve roots reached by the solution. Conduction of impulses along the nerves springing from these roots is blocked and the corresponding areas become insensitive. The course of the analgesia is segmental. It rises after a lumbar injection from the fourth or fifth sacral to the umbilical region, or higher, according to the amount and manner of the injection, as has been above explained. The insensibility produced varies not only as to the height which it reaches, but as to its intensity. That is to say, the abolition of pain sensation is usually complete for the segmental areas, the innervation of which is involved in the injection, but even this abolition is not absolute. Motor paralysis of the lower limbs is generally present, but may be incomplete. There is sometimes relaxation of the sphincters of bladder and of rectum. Painful sensations, as produced by cutting, may be entirely absent while those due to dragging may remain. The sensation of touch often persists when that of pain is completely absent. Whether the injected fluid acts on the cord itself does not seem certain, but most authorities believe that such action, if present, is very slight, and that the phenomena produced are due almost entirely to action upon the nerve roots, especially the posterior of these. Repeated injections of stovaine were shown by Spiller and Leopold [1] to produce degeneration of the posterior roots in dogs. There is no evidence of permanent change ever being produced in the human subject unless through sepsis. Transient paralysis of the abductor muscles of the eye, however, lasting sometimes for weeks, has often been recorded. The most common objectionable *sequel to spinal injection* is intense headache. The cause of this is not clear. Absolute stillness during recovery is thought to lessen its frequency. Some attribute the headache to excessive loss of cerebro-spinal fluid. On the other hand, the headache has been relieved sometimes by lumbar puncture and withdrawal of about 20 c.c. of cerebro-spinal fluid.[2] Barker found that fluid withdrawn within forty-six hours of injection of stovaine was always turbid, the turbidity being due to the presence of leucocytes. Page [3] states that in his practice headache has become rare and negligible since he reduced the dose injected, limited the escape of cerebro-spinal fluid, and used freshly prepared solutions.

[1] *Journal Amer. Med. Assoc.*, June 4, 1910.
[2] *Proc. Royal Soc. Med., loc. cit.*
[3] *Lancet*, April 26, 1921, p. 800.

Administration.—Barker's solution of stovaine, 10 per cent.; glucose, 5 per cent.; distilled water, 85 per cent., kept in hermetically sealed ampoules (Billon) which provide 6 centigrammes of stovaine in 2 c.c., is an excellent agent for those who prefer to use a comparatively non-diffusible liquid, the position of which can be controlled for a short time after injection. Some prefer a 10 per cent. solution of stovaine in normal salt solution, and prepare it freshly for themselves. If novocaine is used tablets can be employed or freshly prepared 1 per cent. solution, or ampoules of Braun's novocaine and suprarenin. Six centigrammes of stovaine is an average dose for a man. Care must be taken that no soda is used in sterilizing the needle and syringe. Barker's hollow needle, cannula, stylet, and syringe form a convenient instrument to use for spinal injection (Fig. 48). These having been sterilized in plain water, lie on a sterile towel. The ampoule is held and its neck broken by an assistant while the anæsthetist, with sterilized hands, loads the syringe from the ampoule, sucking up the solution through the hollow needle. This is then detached from the syringe, which is placed in readiness on the sterile towel beside the needle, now threaded with the stylet, and the cannula. The skin of the lower dorsal and lumbar spinal regions being cleaned with iodine or with ether, the patient is placed in the required position for injection. This is either sitting or lying. In either position arching of the back is procured so as to obtain the greatest possible space between the spinous processes. In the sitting position the patient's buttocks rest on the edge of the side of the table, his feet on a chair, and he leans forward with his hands on his knees, his head lowered, and his back bowed as much as possible. For the lying position he is placed on one side, his thighs are fully flexed, the knees being drawn up towards the chin, and his head and neck, supported by a pillow, are bent well forward towards the chest. The position of the fourth lumbar spine is made out by reference to the highest points of the iliac crests, the skin over which has also been sterilized, in order that it may be palpated if the anæsthetist desires. A line joining

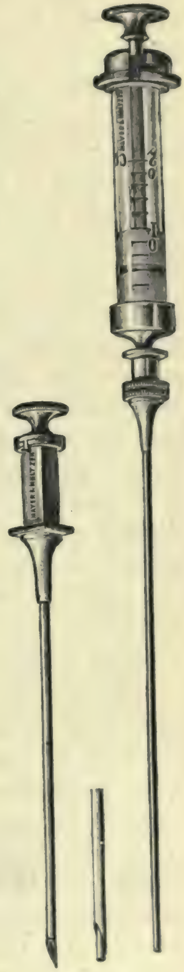


FIG. 48.

these two points passes over the spinous process of the fourth lumbar vertebra. The injection may be made between this and the third spine, or between the third and second spines, or, as Rood prefers, between the eleventh and twelfth dorsal spines. Some prefer to nick the skin at the selected point with a sharp, narrow tenotome and plunge the needle through this tiny wound. When this is not done the forefinger of the left hand is pressed against the spinous process below which the injection is to be made. The needle, held in the right hand, presses along the pulp of this finger, and with a firm push is made to pierce the skin and the interspinous ligaments. The stylet is now withdrawn, if Barker's instrument is being used, and the needle pushed in is felt to penetrate the dura almost like passing through paper. Cerebro-spinal fluid should now escape in rapid drops or in a little stream. A half-turn is then given to the needle. A finger of the left hand now temporarily shuts the open needle when the fluid is escaping, while the right hand takes the syringe, loaded with the cannula, pushes this through the needle, and makes the injection slowly and firmly. The depth to which the needle has to be pushed before fluid escapes varies according to the fatness of the patient's back. Usually it is between 1 and 2 inches. If blood escapes, or if no cerebro-spinal fluid escapes, after passing the stylet and slightly moving the needle's point, a fresh puncture must be made. So long as some cerebro-spinal fluid is seen to come out the injection may be made with good hope of success. The technique just described is variously modified. Some French workers collect the escaping cerebro-spinal fluid and reinject it with the anæsthetic solution, or employ it to dissolve the anæsthetic substance which they have in the receiving tube in the form of crystals or a powder. Again, as already mentioned, some authorities believe that the height to which the analgesia extends depends on the amount of cerebro-spinal fluid allowed to escape. Bloch,[1] for example, recommends that at least 30 c.c. should be withdrawn. He injects 12 centigrammes of novocaine, usually with adrenalin. The *duration of analgesia* is usually about one to one and a half hours, and is longer with a large than with a small dose. The first evidence that the injection has taken effect is generally a feeling of numbness and heaviness about the feet and legs. Within a few minutes analgesia can be demonstrated on the thighs and perineum. Some power to move a foot or even a leg commonly persists. Within the first twenty minutes of the injection it is not uncommon for pallor with feelings of sickness or actual retching to attack the patient. This is probably associated with low blood pressure, possibly with the

[1] *La Presse Médicale*, April 20, 1921, p. 317.

reduced respiratory excursion and poor venous return from the splanchnic vessels. Actual syncope has occurred. It is less often seen when the head is allowed to be low after the first few minutes. Sometimes there is an oppressive feeling of want of air on the patient's part. With high analgesia occasionally there is actual stoppage of the breathing, and artificial respiration and raising of the legs are needed. Oxygen should be used on these occasions. Persons who are already in a *state of shock*, or who, owing to the condition of their heart or circulation, are liable to danger if the blood pressure is lowered, should not receive spinal injections. In a fully conscious patient there is always a certain amount of pain due to the actual injection. Even if the skin is rendered insensitive there is pain when the dura is pierced. One patient compared the pain to "being hit in the back with a cricket ball." It is only in certain persons that pain like this just before an operation can be treated with indifference. In all others it is far better that their sensibility should be dulled by previous narcotic injection or that they should be actually unconscious before the injection is made. When the latter course is not pursued the writer precedes the spinal by hypodermic injection of omnopon (gr. $\frac{1}{3}$), scopolamine (gr. $\frac{1}{100}$), and atropine (gr. $\frac{1}{120}$) one and a half hours before operation. This is followed by either omnopon (gr. $\frac{1}{3}$) or scopolamine (gr. $\frac{1}{200}$) half an hour before the administration of the spinal anæsthetic. The lying position is generally to be chosen for people who have been previously treated in this manner. Provis [1] has recommended that an actual twilight sleep should be secured before using spinal injection for gynæcological operations. The hypodermic injections advised above do often produce a state of somnolence or amnesia amounting to twilight sleep. By plugging the ears and bandaging the eyes the effect can be enhanced. The conditions in which spinal analgesia should be the method of choice have been sufficiently indicated in Chapter XV. As a routine method of anæsthesia for operations below the umbilicus and in the lower limbs it may be chosen or not in preference to general anæsthesia, according to the taste and experience of the operator.

Sacral Analgesia

Epidural or Extra-thecal Injection

By injecting anæsthetic solutions into the sacral canal the sacral and coccygeal nerves in the cauda equina may be paralysed and the region that they innervate rendered insensitive. Moreover, if the solution is made to travel up within the spinal column,

[1] *Lancet*, Jan. 26, 1918, p. 152.

although outside the dura mater, the nerve roots emerging from this may be affected wherever the solution reaches them. Coloured solutions injected into the sacral canal in the cadaver have been shown to travel up as far even as the attachment of the dura mater to the base of the brain.[1] Mr. Whyte-Venables, using 100 c.c. of carbol-fuchsin, injected a cadaver at my instigation, and found that the stain never penetrated the dura, but was to be seen along all the nerve trunks coming from the cord throughout its length. This corresponded exactly with Thompson's results.[1] This observer appears to have used smaller quantities of solution, but nevertheless it travelled to the summit of the spinal column. Clinical experience coincides with these injections made on the cadaver. Analgesia, that is to say, has been found at high levels when injections have been made into the sacral canal. Although used at first only for operations on perineal, pelvic, or genital organs, the method seems successful for operations at higher levels. Experience with it, however, is not yet wide so far as operations above the pelvis are concerned. At any rate, it is not possible to find recorded accounts of these. The author has used it with perfect success for removal of a chronically inflamed appendix, and Rood informs him that he has applied it with satisfaction to laparotomy for excision of malignant growths of the bowel. Lockhart Mummery has employed sacral analgesia for anal and rectal operations during the last five years, but found it uncertain. This defect, however, may be due to the use of too small quantities of the anæsthetic solution. Experience shows that considerable amounts can be safely injected into the sacral canal without adverse symptoms. In order to ensure success the administrator must not stint his dose of the solution. Using 2 per cent. novocaine, he should rarely insert less than 40 c.c., unless the operation is a small one in the perineal or anal region. Also he must allow plenty of time for the solution to take effect. The full result is not generally present till half an hour or so has elapsed since the injection was made.

One or two *anatomical points* must be borne in mind. The dura mater ends usually at the upper border of the second sacral segment, after which the sacral and coccygeal nerves run free in the bony canal of the sacrum, surrounded by a little loose areolar tissue, until they issue at their respective foramina. The spinous process of the fifth sacral segment is represented by two knobs of bone, the sacral cornua. Between these knobs on each side and the tip of the sacrum below is the sacral hiatus, a gap bridged by firm membrane and guarding the entrance to the sacral canal. It is by piercing this membrane that injection is made into the

[1] J. E. Thompson, *Annals of Surgery*, Vol. 66, 1917, p. 718.

canal. These anatomical features are liable to much variation, the sacrum being inconstant in its formation, especially in its lower part. The two portions of bone representing the fifth sacral spine may be unequal in size, and the hiatus may not lie in the middle line. It may be very narrow, or it may be unusually large, the fourth sacral spine as well as the fifth being divided. The reader will find further details of the local anatomy in Thompson's paper,[1] to which reference has already been made.

Administration.—Preliminary hypodermic injection of alkaloids is always advisable, and the writer has used generally omnopon, scopolamine, and atropine an hour and a half before operation, followed by either omnopon or scopolamine an hour later (see p. 303). The skin is cleaned over the sacral spines down to the anal cleft. The patient lies comfortably on one side, the head on a pillow and the legs slightly drawn up. On a sterilized towel near at hand are—

(1) Small sterilized basin containing 100 c.c. 2 per cent. freshly made novocaine solution into which have been dropped 20 drops of 1 to 1,000 adrenalin. A sterile flask with another 100 c.c. in case of need.
(2) Record syringe of 20 c.c. capacity.
(3) Needle to fit this, at least 2 inches long.
(4) Small hypodermic syringe and needle, containing 5 c.c. of the novocaine-adrenalin solution.

The anæsthetist, with sterilized hands, arranges sterile towels to surround the sacral area, buttocks, and perineal region. He then finds the tip of the sacrum at the upper end of the anal cleft and feels firmly upward with the pulp of a finger till he defines the pit between the two bony prominences of the divided fifth sacral spine. This spot is about an inch above the tip of the sacrum. Having fixed it with a finger of the left hand, he injects a drop or two from the hypodermic syringe into the skin. Then he presses on the needle and injects a few more drops into the membrane guarding the sacral canal. Now he takes the larger needle and thrusts this through the puncture till it pierces the membrane guarding the sacral hiatus at a depth of about ½ inch from the skin. Feeling that he has pierced the membrane, he depresses the needle till its axis is that of the sacral canal and pushes it firmly upwards for about 2 inches. If he has successfully entered the canal he can wobble the needle easily from side to side, but can hardly move it forwards and backwards. Then he fixes on the syringe, having filled it from the basin, and slowly injects its contents. If the needle is correctly in the canal, the

[1] J. E. Thompson, *Annals of Surgery*, Vol. 66, 1917, p. 718.

solution flows in easily and no swelling is seen. If, on the other hand, it has been passed superficially to the canal, œdema or swelling soon shows itself in the course of the injection. The needle must then be withdrawn and a fresh entrance made. The point of the needle may be in the canal, but involved in the tough tissue lining its bony wall. Injection then is only made with firm pressure. The ease with which the solution is injected and the entire absence of ocular evidence of its presence are generally the best criteria that it is being sent into the canal. If the membrane guarding the hiatus has not previously been made insensitive by a drop of novocaine there is a painful moment when the needle pierces it. This momentary pain is good evidence that the canal has been entered. According to Meaker [1] it is only possible to tap the spinal theca, which is, of course, not desired, if there is an abnormally low dural sheath, an abnormally capacious sacral canal antero-posteriorly, or if a curved needle is used. Analgesia is slowly developed, but as repeated syringefuls are injected its upward advance can often be easily followed by pinching and questions. Sense of touch and pressure does not disappear, nor is motor paralysis complete. I have not seen relaxation of sphincters with discharge of urine or fæces, as sometimes appears after intra-thecal injection. The anal sphincter, however, is very easily stretched without causing any pain. Analgesia as high as and including the face and scalp has attended injections which have been made of large quantities of the solution, 100 c.c. and over. The drowsy mental condition which is often present may in part be due to the novocaine injection. Rood has noticed a tendency to attacks of clonic convulsion amounting to a real rigor. These attacks are brought on by moving or disturbing the patient. In my own cases, however, the mental condition of the patients has been attributable chiefly, I believe, to the preliminary narcotics, and to the same cause I attribute a peculiar mental state that has sometimes been present in these patients for twenty-four hours or so after operation. Usually they have shown amnesia, not remembering the sacral injection at all. In addition they have been what the ward-sister described as "queer," not, apparently, understanding properly what has been said to them. They have not been violent or restless, but rather somnolent and lethargic, though easily roused. The few blood pressure observations made during this analgesia have not shown a lowering at all equal to that produced by intra-thecal injection.

Sacral analgesia brought about by injection of novocaine promises to be a valuable addition to the means of procuring

[1] *Brit. Med. Journal*, May 10, 1919, p. 570.

local insensibility. There have been, so far as I am aware, no injurious sequelæ, and the immediate effects should be, and apparently are, more free from any depressing influence on the patient than injections into the theca. The uncertainty of action which at present depreciates the value of sacral injection may well be dissipated by wider experience. A like uncertainty attended the early use of spinal injections and was only abolished by perfected detail in technique. In my own experience the method has answered admirably for prostatectomy, removal of appendix, operations on hæmorrhoids and on inguinal and femoral herniæ. Used for an excision of the rectum it gave at first so apparently poor an analgesia that it was supplemented by an intra-thecal injection. Analgesia was then perfect, and remained during so long an operation that the surgeon was convinced that the sacral injection had in reality taken effect.

CHAPTER XXIII

THE FATALITIES OF ANÆSTHESIA

Medico-legal and Educational Questions

In the foregoing chapters we have seen that many of the phenomena witnessed during anæsthesia are only partly, if at all, due to the anæsthetic. The same is true of deaths which occur during anæsthesia. Many of these are not anæsthetic deaths properly so called. They are deaths occurring during, but not owing to, anæsthesia. In some instances the condition of the patient is such that death is already imminent before the anæsthetic is inhaled at all. In the same category come all instances of death from hæmorrhage, and many of those from surgical shock, which happen on the operating table. Deaths which occur from mechanical interference with respiration, as, for instance, from inspiration of foreign matter into the air passages or from bursting of an empyema into the bronchus, are equally to be excluded from the class of true anæsthetic deaths. When, it may be asked, are we to reckon a fatality one which is justly to be called a "death from an anæsthetic"? The description can properly be applied when a person in ordinary health dies while under the influence of an anæsthetic either before operation has begun or during or after the performance of an operation involving no severe shock or hæmorrhage, and provided that no mechanical cause of death has arisen. It is necessary to add the last proviso, for it is obviously not right to attribute to anæsthesia a fatality, for instance, which is due to inhalation of vomit during recovery. The death would be prevented by proper treatment directed in no way to the anæsthetic. The latter cannot, therefore, be held primarily responsible. Such a death is due, in the first place, to a faulty position of the patient and only secondarily to the anæsthesia.

The dangers most likely to be associated with the different anæsthetics have already been to some extent described and their avoidance and treatment considered. Now we may with advantage see if the fatalities of anæsthesia can help us to arrive at

some systematic guidance in practice from the lessons of the records. Deaths in anæsthesia present a complex problem whether they are looked at from the purely scientific, the practical, or the medico-legal aspect. For thorough scientific understanding of these fatalities we need the help of experiment to a greater extent than it has been available. Granted this, we are still confronted with the differences, mental and physical, between man and the animals of the laboratory, even if the exact conditions of clinical practice are reproduced on the physiologist's bench. Again, the problem is complicated by the varying nature of the data offered. Even if the anæsthetic and the anæsthetist in a long series of recorded cases are constant, the patients offer wide variation in natural constitution, in the illnesses from which they suffer, and in the operations which they undergo. It is easy to see, then, how difficult it may be in any fatality during anæsthesia to apportion accurately the share of the blame. In one case it may be obvious that the patient's state was such that death was not far off even without operation. In another the operative shock or the hæmorrhage may clearly be sufficient to account for death. We should attempt first of all to regard these fatalities as divisible, so far as anæsthetics are concerned, into two main classes. The first contains those fatalities for which the anæsthetic may fairly be held to be the main responsible factor, the second those in which it is only more or less contributory. The first class includes cases in which either no operation at all has begun or the operation has been of a trivial nature. These cases in which the anæsthetic is the sole extraneous factor must be divided again into—

(*a*) Healthy subjects ;
(*b*) Persons whose condition prior to taking the anæsthetic was not normal.

The instances in class (*a*) are those which alone can rightly be spoken of as "anæsthetic deaths." Even here it is possible that the emotion of terror, which in pre-anæsthetic days led to death before the stroke of the knife, may have played some part. Yet, taken as a whole, this is the class of case which may most fairly be taken to give us guidance as to the relative safety of different anæsthetics. If in many thousands of administrations we find that fatalities in healthy subjects before operation has begun occur solely or much more frequently when one anæsthetic is being used rather than another, we have grounds for regarding the first as a more dangerous agent than the second. In the records of many thousands of administrations the occurrence of death during inhalation of an anæsthetic and before the beginning

of operation is almost limited to the inhalation of chloroform or mixtures containing chloroform. In comparing the relative safety of anæsthetics **we have this ground for regarding chloroform as the most dangerous.** This opinion is further fortified by the fact that in a wide record of fatalities during anæsthesia, gathered from the Registrar-General's returns, the cases in which chloroform, or mixtures containing chloroform, was used are not less than 72 per cent. of the whole number, and are generally more. The returns of the Registrar-General for England and Wales are based upon the death certificates signed by medical men all over the country. Although, therefore, we may examine his figures with interest and give them due importance as covering a wide field, yet in drawing conclusions we must remember that they have the defect of all statistics in which we are ignorant of the value to be placed upon the judgment and knowledge of those who supply the figures. Examining the figures for the eight years 1912 to 1919, one is struck first of all by the remarkably even level at which the number of deaths during anæsthesia remains from year to year. In 1912 there were 167 deaths among males and 116 among females. In 1918 the figures were 182 and 120, and all the intervening years give figures very near these. These figures include all deaths in the certificates relating to which any mention is made of the administration of an anæsthetic. It is, of course, possible that there are certificates from which such mention is omitted. And each year there are some fifty to sixty certificates in which the nature of the anæsthetic is not mentioned. Perhaps the next most remarkable feature is the prominence given to the status lymphaticus as the primary cause of death in recent years. For instance, in 1913 to this as a primary cause are attributed no less than 180 fatalities. In 1919 eight deaths are attributed to "delayed chloroform poisoning" and two to "acidosis." In 1917 there were only 16 per cent. of the deaths in which chloroform was not used at all. It is obvious that these statistics, containing slight or no information as to the patient's condition before operation, the nature of the operation, the experience of the anæsthetist, and other important points, cannot help us very materially in our understanding of death from anæsthesia, or even in our estimate of the relative safety of different anæsthetics. For the latter purpose we should have to know not merely how often death occurred during the use of the different agents, but the whole number of times that the different agents were administered. Some statistics are available which help us from this point of view. Thus an account has been provided [1] of the results of 2,171,461 admini-

[1] *American Journal Surgery* (Anæsthetic Supplement), April, 1917, p. 51.

strations by various agents. The mortality is here stated as being—

From ether, one in 8,010 ;
From chloroform, one in 2,605 ;
From ethyl chloride, one in 13,365 ;
From spinal analgesia, one in 515 ;
From scopolamine, one in 666.

As regards the relative safety of ether and chloroform, these comparatively recent figures bear out the usually accepted opinion. Hewitt [1] gives tables showing 676,767 administrations of chloroform with a death-rate of one in 3,162 and 407,553 ether administrations with a death-rate of one in 16,302, and states that we may regard ether as being about six times as safe as chloroform. The Anæsthetics Committee of the British Medical Association reported eighteen deaths in 13,393 chloroform administrations and seven deaths in 6,666 administrations of ether or " gas and ether." Gwathmey [2] in a table relating to 278,945 administrations in ninety-nine different hospitals of the United States gives an ether mortality of one in 5,623 and chloroform one in 2,048. Nitrous oxide with air or oxygen was used 9,146 times with no death. It is noticeable that in the Registrar-General's returns the **male deaths always exceed the female where chloroform is concerned,** and generally with the other anæsthetics also. Yet probably the number of operations yearly on females is as great as that on males. We shall very likely be right in assuming that the greater muscular development of the male, rendering spasm both more likely to occur and more formidable when it does, makes him a worse risk for anæsthesia than the female. The **influence of age** on anæsthesia mortality is not easily determined by available statistics, but the especial liability of children and young adults to status lymphaticus and " delayed chloroform poisoning " as causes of death is made plain. The Anæsthetics Committee of the British Medical Association reported (1900) that chloroform is twice as dangerous to males as it is to females, and that it is most dangerous in early infancy and after thirty years of age.

The relative safety of ether and of chloroform has been studied for so long that it may now be regarded as fairly settled. Nobody with knowledge of the facts any longer denies that danger arises much more easily when chloroform is used. The contention that ether more often leads to fatal consequences after operation is considered elsewhere.

With regard to the third common anæsthetic, nitrous oxide,

[1] " Anæsthetics," 1912, p. 139.
[2] " Anæsthesia," 1914, p. 843.

we are on less sure ground. So far as short operations are concerned, universal record and opinion put nitrous oxide with air or oxygen in the first place of all general anæsthetics as regards safety. Hewitt records 20,000 administrations with no death and with only two or three occasions when symptoms caused any anxiety. We have seen that nitrous oxide has no toxic action and that when it brings about death this is always by way of asphyxia, and that, therefore, the anæsthetist in almost every instance will have warnings obvious even to the inexperienced. Persons in whom asphyxial conditions arise with undue ease, *e.g.*, those suffering from cellulitis of the neck or any pressure on air passages, and those with hearts that fail under the strain of a slight asphyxia, constitute the dangerous classes for this anæsthetic.

Of recent years nitrous oxide and oxygen have been frequently employed in major surgery, and the question arises, is the striking safety of nitrous oxide for short operations also provided by long administrations of this anæsthetic? It stands to reason that when an anæsthetic is used during operations which may become dangerous of themselves, or for patients whose condition makes any operation risky, deaths will occur during the use of that anæsthetic. Consequently, now that nitrous oxide and oxygen are often used for severe operations and for people who are gravely ill, deaths have occurred during the employment of these gases to an extent that was hitherto unknown. It by no means follows that those deaths would not have occurred if another anæsthetic had been used, or indeed that they might not have occurred with greater readiness. The Registrar-General's returns give us as yet very few recorded deaths attributed to nitrous oxide in Great Britain. In America, where this anæsthetic with oxygen has longer been in vogue for major surgery, we find a considerable record. Connell [1] states: "Since the extensive introduction of this gas into general surgery the reported and unreported deaths have probably far exceeded those from ether." Gwathmey in 1915 reports a fatality under "gas and oxygen," of which he says: "The death was absolutely uncalled for and has changed my ideas of the safety of nitrous oxide and oxygen entirely. I believe if I had given him ether the man would have been alive to-day." Other authorities are quoted in the article [1] above alluded to proving the not infrequent occurrence of fatalities during the use of nitrous oxide and oxygen for major surgery. At the same time the details given of the operations or of the patient's condition beforehand are generally so scanty that it is hard to appraise accurately the responsibility or innocence of

[1] *Medical Record of New York*, July 29, 1911.

the anæsthetic. It is probable, however, from the writings of others and from one's own experience, that the safety of "gas and oxygen" for long operations is not on a par with that of the same anæsthetic in short procedures. Moreover, opinion is general that with this more than with any other form of anæsthesia for major surgery skill and experience are essential for safety. "Gas and oxygen" may be the safest anæsthetic even for long operations; it is certainly the most difficult with which to succeed. It is worthy of note that nitrous oxide self-administered has been the accidental cause of death.[1] The not uncommon practice of testing the gas upon oneself is dangerous if the subject is so placed that, should he become unconscious, the face-piece does not necessarily fall away from the face. In the case alluded to a dentist had applied the face-piece to himself while recumbent in his chair. It is believed that on the occurrence of unconsciousness tonic spasm of muscles kept the face-piece against his face, where it was found, with the cylinder still supplying gas and the dentist dead.

The safety of **ethyl chloride**, which is used almost entirely either for short operations or as an introduction to other anæsthetics, is generally computed as being somewhere between that of ether and that of chloroform—safer than the latter, less safe than the former. Luke [2] gives a list of twenty-five fatalities, but in a letter to the *British Medical Journal* [3] during a discussion on the safety of ethyl chloride he states that records of deaths under this anæsthetic during recent years are hard to find. The Registrar-General's returns for the years 1912 to 1919 inclusive give fourteen deaths attributed to ethyl chloride. McCardie put the mortality from ethyl chloride at one in 3,000, other authorities at one in 7,000.[4] My own experience of this anæsthetic used only for short operations is favourable, as no fatality occurred in 3,550 administrations. Moreover, except for delay in recovery with feeble pulse, I have met with no untoward symptoms, and have never had to adopt any restorative measure beyond one or two compressions of the chest.

Since the majority of deaths during anæsthesia take place under chloroform, we may with advantage first attempt to elucidate these in our search for the practical lessons that fatalities may teach us. The physiological explanations of death from chloroform have been detailed (Chap. V.). We must here consider the clinical presentation of these phenomena, for doubtless death

[1] *Lancet*, Dec. 4, 1920, p. 1167.
[2] "Anæsthesia in Dental Surgery."
[3] *Brit. Med. Journal*, Nov. 22, 1919.
[4] Hewitt, *loc. cit.*, p. 456.

in the human subject under chloroform is due to the same disturbances which the drug produces in the laboratory. There are two different kinds of death seen under chloroform in practice. In one there is rapid collapse of the patient, the heart appearing to stop abruptly while the respiration continues for a little while, or both may apparently cease with equal suddenness. The patient turns pale, the pupils dilate widely, the globes of the eye roll back, and the lids slightly separate. One or two gasping respirations may be drawn at intervals of several seconds. This sudden failure occurs during the induction stage or during recovery from the anæsthetic. It may happen during operation if the anæsthesia is incomplete. The reader will find an admirable example in the *British Medical Journal* for June 14, 1919, and a prolonged discussion of the accident by various authorities in the subsequent numbers. In the other kind of fatality the failure occurs more gradually. The breathing may be seen to be getting feebler and feebler and the patient growing paler or cyanosed. Often these symptoms have heralded the fatal end of a long or severe operation under chloroform. Fatalities of the latter class are probably always preventable if the onset of danger is detected early enough. They represent the toxic effect of too much chloroform on the vital centres, the respiratory probably being the first to fail. The first class, which comprises the instances of syncope during chloroform narcosis, is the larger and represents deaths many of which can probably not be averted if chloroform is used. They correspond to those experimentally produced deaths which the physiologist attributes to ventricular fibrillation (Levy) or to vagal and vaso-constrictor inhibition (Embley). In practice they are met in healthy muscular subjects rather than in the feeble, during the early stages of operation or before operation is begun, and in a stage of narcosis which is not very deep. The corneal reflex may be absent, but there is no enlargement of pupil due to chloroform, and there are no symptoms to suggest over-dose before the sudden circulatory failure. In some instances clinically spasmodic interruption of breathing undoubtedly plays a part, and these fatalities do not correspond with any that are reproduced in the laboratory. It may be that even in them fibrillation of the heart muscle or heightened vagus action has an influence, but certainly there are present the factors of a right heart over-distended by lung inaction and heart muscle subjected to the influence of chloroform which is not being eliminated. In practice the factor of *intercurrent asphyxia* is probably present before many fatalities, and is instrumental in bringing them about. It must always be remembered that under chloroform asphyxia may be an insidious condition. The breathing and the heart may

be lowered almost to the point of cessation by asphyxia during chloroform inhalation with little or no objective symptoms beyond cyanosis. Unless the obstruction to respiration is recognised because of cyanosis and the cause rapidly removed, the subject may be quietly and rapidly asphyxiated (Levy). It is the common occurrence of an asphyxial element often unrecognised on which Hewitt laid so much stress as a frequent cause of danger, and he believed that this factor was responsible for a large proportion of anæsthetic fatalities.

Pure over-dose from the inhalation of an excessively strong vapour does not appear to be a common mode of death. On the other hand, gradual over-dosage in the course of an operation, during which the combination of surgical shock and lowered breathing renders an ordinarily safe strength of vapour dangerous, may account for a number of fatalities. It is worthy of note that there is nothing in the symptoms to distinguish a chloroform death associated with *status lymphaticus* from one not so associated. The deaths which have occurred and have been attributed *post mortem* to that condition have exactly resembled in their onset other sudden deaths under chloroform when no status lymphaticus has been found *post mortem*. We may infer that although the condition may render its subjects especially liable to circulatory failure under chloroform, yet the way in which that failure is brought about does not differ in them from the way in which it is brought about in the normal subject. Levy, who strenuously upholds the view that chloroform deaths are due to ventricular fibrillation, and not to over-dosage, reviewed the records of ninety-eight deaths collected by the Anæsthetics Committee of the Royal Medico-Chirurgical Society, and found that in 87 per cent. death could not have been due to over-dose. He states that in all ninety-eight reports not one gave definite evidence that the patient died of over-dose. Sixty-two per cent. of the patients were thought to be lightly anæsthetized at the moment of death. We must remember, however, in accepting this evidence that no human administrator is likely to admit readily that he had given an over-dose. He will need a very judicial mind to be able to convince himself of that and an unusually fearless and candid disposition to state his conviction publicly. Moreover, from many years' observation of administrations by the inexperienced I am convinced that they are often unaware of the depth of narcosis to which they have led their patients and that they may overdose them unwittingly. In short, **over-dosage may be a negligible cause of death where experts are concerned; it is not so with the inexperienced.** How, then, is the expert to avert the danger which accrues in light stages of

chloroform narcosis when the drug is administered only in proper strength ? Perfectly continuous administration and not too slow an increase, avoidance of all asphyxial complications, and avoidance of all external stimuli before full narcosis is reached are the measures to be adopted. It must be confessed, however, that even with these the danger zone has to be traversed and that there is no absolute escape except by the avoidance of chloroform. The most skilful and careful expert possible, if he uses nothing but chloroform, will sooner or later meet with an occasional fatality, just as the physiologist in the laboratory loses an occasional animal even with his carefully regulated machinery for giving chloroform. Moreover, in the human subject there is the added difficulty which may arise from the upper respiratory tract, a difficulty which is generally cut out in the laboratory by tracheal administration. The danger due to individual peculiar susceptibility to chloroform must also be recognised. There is no doubt that, just as occurs with morphia and other powerful drugs, some individuals will exhibit symptoms of toxæmia under doses of chloroform that would be harmless to other individuals. This is what is meant when idiosyncrasy towards chloroform is spoken of.

The *post-mortem appearances* of a subject who has died from an anæsthetic give little or no help in determining how the death has been brought about. In practice, moreover, the efforts that have been made to restore life alter in important respects the exact conditions present when life ceased. Thus the state of the heart and lungs has generally been modified by the performance of artificial respiration from that which they presented at the moment of death. Movement of the body after death may also alter the disposition of the blood. Thus it happens that *post-mortem* examination rarely provides evidence pointing to the degree of narcosis present when life ceased. It might be expected that if death happened in the early stages we would find a congestion of the brain and spinal cord that would be absent in deep narcosis. Snow found that in animals killed by chloroform the right side of the heart was filled with blood while the left contained little. Schäfer and Scharlieb, on the contrary, state that in animals killed by chloroform, if the examination is made immediately after death, all the cavities of the heart are distended with blood. If, however, the examination is made some little time after death, the left ventricle is empty and firmly contracted. Kunkel[1] states that the heart killed by chloroform always stops in diastole and that contraction of the left ventricle is a *post-mortem* appear-

[1] "Handbuch der Toxicologie," Pt. I., 1899, p. 449.

ance. MacWilliam states that in animals it is impossible to say from the *post-mortem* condition of the heart whether death under chloroform has been due to primary cardiac failure or to asphyxia. In many *post-mortem* examinations of persons who have died during anæsthesia the chief appearances are those which are found in subjects who have been suffocated. Commonly there is more blood in the right side of the heart than the left, congestion of the portal system and abdominal viscera, of the superficial vessels of the brain and of the lungs. The blood after death from chloroform remains darker and more fluid than usual. The smell of chloroform quickly goes, and it is said (Taylor) that neither smell nor analysis can reveal chloroform half an hour after death. Ether, on the other hand, can be perceived by the smell if the viscera are cut into as long as twenty-four hours after death has taken place during administration. When death has depended on *nitrous oxide* inhalation the appearances *post mortem* have been those of asphyxia.

Two interesting fatalities during nitrous oxide inhalation are related in the Medico-Legal Society's *Transactions* for 1919–20. One shows the well-known danger of using this anæsthetic when there is mechanical respiratory obstruction present, and the other shows that death may occur in a feeble subject from shock during the inhalation of "gas and oxygen" without any asphyxial element playing a part.

(1) "A chimney sweep had the entire tongue removed for epithelioma. After three months he grew emaciated and recurrent growth appeared involving the epiglottis, thyroid, and deep-seated glands of the neck. Six months later he was readmitted to hospital in order that radium might be used. There was now some difficulty of breathing. Pure nitrous oxide was administered and a tube of radium thrust into the growth. The patient coughed and expectorated the tube. Accordingly he was given some more gas and the tube reinserted and sutured in position. The operation lasted about five minutes. Just as it finished the patient turned pallid and respiration and cardiac action ceased simultaneously. All efforts at resuscitation failed." Here, although details of the effects of the gas are scanty, we may reasonably suppose an accentuation of the "difficulty of breathing" that had been noted and an asphyxial heart failure secondary to this.

(2) In the second case the mode of death was probably quite different. "A thin, wasted woman, who had attended a throat hospital for carcinoma of the œsophagus, was suffering from dysphagia and some dyspnœa. Six weeks after admission to hospital a preliminary injection of morphia, hyoscine, and atropine was given and nitrous oxide and oxygen administered for the operation of gastrostomy. About five minutes were spent in induction, and the operation was performed in about twenty-five minutes. It was just concluded when marked pallor and collapse supervened; the pupils dilated widely and the respiration ceased. Artificial respiration was kept up for twenty minutes, oxygen administered, and pituitary extract injected. *Post mortem* the brain and membranes showed nothing abnormal. At

the upper end of the œsophagus was an extensive malignant growth almost occluding the œsophagus. The growth had ulcerated through and partially closed the trachea. There were growths in both lungs. The heart was very small and atrophied (brown atrophy). The mode of death was stated to be 'heart failure accelerated by the shock of operation while under the influence of nitrous oxide and oxygen,' and it was stated that 'the death was not due to the anæsthetic.'"

In an account of a *post-mortem* examination after death under *ethyl chloride* Hewitt states that on opening the thorax there was a strong smell of the drug. The heart muscle was flabby and easily friable with dilatation of right auricle and ventricle and of left ventricle. The heart muscle showed both fatty infiltration and degeneration. The brain was congested, with œdema of its surface. The lungs were both deeply congested, and a small amount of mucus was in the bronchi. The patient was a man of sixty-seven, well nourished, but short-necked and with rib cartilages ossified. The danger of ethyl chloride lies chiefly in its power to depress the blood pressure. No evidence of this, of course, appears *post mortem*. The fatal fall of blood pressure is in some instances, however, preceded by spasm and interrupted breathing. When this happens the *post-mortem* appearances resemble those caused by asphyxia pure and simple.

Are Fatalities Preventable?

Having arrived at some idea of how fatalities commonly occur during anæsthesia and of the extent to which the anæsthetic itself is to be held responsible, the anæsthetist must face the practical question, "Are these deaths preventable?" Deaths that are due entirely to the anæsthetic we have seen to be limited practically to a certain kind of fatality occurring during the inhalation of chloroform. This particular variety of death has occurred in the hands even of the most skilled. These fatalities, if any, may be regarded as inevitable, provided that chloroform has to be employed for induction of anæsthesia. It is impossible to state their frequency, but probably it amounts to no more than one in many thousands of administrations. With regard to all other anæsthetic fatalities, we are bound to believe that very many are preventable. The more experienced and skilled is the anæsthetist the less frequently do they occur in his practice. Consequently we infer that many of the deaths which happen in inexperienced hands would be prevented by more experienced administrators. There is no gainsaying the *dictum* of the Anæsthetics Committee of the British Medical Association: "They are convinced that by far the most important factor in the safe administration of anæsthetics is the experience which has been

acquired by the administrator." This view is upheld not only by careful scrutiny of the available records of fatalities, but by the experience of those who have given large numbers of anæsthetics. In their early years they lose patients in a way which at the time seems to them inevitable. With further experience they carry other patients in an equally precarious condition safely through anæsthesia, and they realize that their earlier losses were in reality preventable. The accurate appreciation of the patient's condition and of just how much operative damage he can stand is only to be acquired by long experience. Yet it is often only by the knowledge thus acquired that an anæsthetist can keep his patient safe or warn the surgeon in time that danger is approaching. Many a death which seems sudden to the administrator has that appearance only because he has not perceived early enough the indications of approaching danger. The slight alterations of breathing or of colour which would warn the experienced eye may easily pass unnoticed by the novice. When they are soon followed by complete arrest of breathing and of circulation this seems sudden to him who has not perceived its forerunners.

In order to make clear the danger which attends certain conditions, cases illustrative of this danger may here be added. They are instances which have been detailed to me in an official capacity by the administrators concerned. These cases illustrate some of the kinds of danger which may lead to death whatever the skill and experience opposed to them. Yet the greater the experience the larger will be the number of such cases in which the patient can be enabled to survive the anæsthesia. These instances have been selected not on account of any unusual character, but for the opposite reason. They are good examples of common kinds of anæsthetic fatality and may be paralleled almost any week in the year. For the *post-mortem* accounts I am indebted to Mr. Ingleby Oddie, His Majesty's coroner for Westminster.

The first case illustrates the danger of a general anæsthetic and abdominal operation for a patient with chronic acute bronchitis and advanced arterial degeneration. In the presence of an acute gangrenous cholecystitis operation was imperative. The problem which a patient of this kind presents is this—will the comparatively inefficient anæsthesia of local injection, for which he was a difficult subject, offer less risk than general anæsthesia ?

"A. S., æt. fifty, chronic alcoholic ; had suffered from bronchitis for some years." Pulse, 134 ; respiration, 40 ; temperature, 97°. Râles audible all over chest. No extra dulness on percussion. Heart sounds

weak, and the first only faintly audible. Abdomen scarcely moves with respiration. Extreme tenderness over right rectus muscle. Any deep palpation impossible. Injection of atropine gr. $\frac{1}{100}$.

C.E. mixture administered on open mask by drops. One layer of domette on mask. Induction took fifteen minutes. At one period there was some cyanosis with slight spasm of jaws and arms, but this quickly passed, and there was no other evidence of excitement. At beginning of operation pupils were small, corneal reflex absent, and the breathing regular. The surgeon made a right rectus incision into the abdomen. Just as the peritoneum was opened the patient became cyanosed and respiration ceased. The tongue was at once pulled forward. The jaw was not in spasm. Oxygen was administered and the chest compressed. Silvester's artificial respiration carried out. No air could be made to enter the chest except when on two occasions there was a slight gasp. Heart massaged through diaphragm and pituitrin injected. The surgeon felt the heart give one or two spasmodic beats after respiration had ceased.

Post Mortem.—Chronic bronchitis ; hypostatic congestion—both bases. Lungs œdematous. Heart dilated and fatty ; atheroma of aorta ; mouths of coronary arteries almost obliterated by atheroma ; aortic valve much thickened and stiffened ; myocardium soft.

Cause of death.—" Syncope under anæsthetic while suffering from bronchitis and aortic disease."

It is worthy of note that in the above " cause of death " verdict from the coroner's court no mention is made of operation. Yet in all probability the immediate exciting cause of death was the peritoneal stimulus.

The notes of another somewhat similar case are worthy of a brief summary.

" A short, thick-set man of fifty-two, with congested face, slight husky cough, and tightly distended abdomen, was admitted to hospital for urgent operation. Examination of the chest showed emphysema, a few râles, and prolonged expirations. The heart was not to be felt, and its borders were obscured by emphysema. Sounds faintly audible without murmur. Pulse 130, regular, full and of low tension. Chloroform was administered on an open mask. After about 50 drops had been given the patient became blue. An air-way was inserted. Open ether was then given till the conjunctival reflex was gone. The pupils were now of medium size. The abdomen was incised. No further anæsthetic given. The breathing became slower and more shallow and the pulse rapid and feeble. No obstruction to breathing and no spasm of jaw. Oxygen given through the air-way. No improvement. Air-way removed and tongue drawn forward. Respiration and circulation feebler and feebler. Artificial respiration had no effect. Finally breathing and pulse ceased practically at the same time."

No *post-mortem* record of this case is available.

As an instance of death after a trivial operation on a subject not apparently seriously ill the following record is given :

" F. B., four months old, a thin, pale child, was brought to hospital for circumcision. The child, crying lustily, was given 2 c.c. of ethyl chloride from a closed bag and anæsthesia rapidly induced. After that a mixture of chloroform and ether was used throughout, the mask being

held about 2 inches from the face most of the time. Conjunctival reflex absent, light reflex present. No cyanosis. Breathing almost inaudible the whole time, but the respiratory movements of lower chest and abdomen could be seen. Pulse felt at angle of jaw, though quick, was strong throughout. Two or three times the pupils dilated, but recovered their small size when the anæsthetic was withheld. Operation took longer than was expected owing to adherent mucous membrane. The patient coughed during separation of adhesions and during the skin stitching. When the anæsthetic was stopped at end of operation the pulse was strong and the breathing rather slow. About five minutes later it was noticed that respiration had ceased. Face white and pupils widely dilated. No pulse palpable. Remedial measures for twenty minutes failed."

No *post-mortem* record of this case is to be found. Nevertheless, as it stands the record appears of value, and it is very doubtful if any *post-mortem* finding would have made clearer the cause of death. It looks as if a feeble infant had been allowed to suffer suboxygenation for too long a period and had received an undue amount of anæsthetic. The immediate cause of death was probably fibrillation of the heart in the recovery period. Each of these three patients was in the hands of a qualified medical man with no special experience in anæsthetics. The first two patients would obviously have run great risk from general anæsthesia in any hands. We have to admit, however, that criticising without having seen the patients is little better than guesswork.

As an example of the well-known danger inherent in severe cellulitis of the neck when the patient is submitted to anæsthetics the following case is recorded :

" A waiter, aged sixty-two, of good health previously, found the right side of his neck swollen on October 10th, 1917. On the 14th he had some teeth extracted from the lower jaw on that side. On the 11th he was admitted to hospital for pyæmia with suppuration in the neck. The neck was incised. On the 17th at 6 p.m. severe dyspnœa set in and the house surgeon performed tracheotomy. A mixture of ether and chloroform was administered by a house physician. The patient was in the dorsal position with the head turned to the left. There was difficulty in breathing from the first and much mucus. Slight excitement. A prop was inserted between the teeth. The breathing was noisy and vigorous. Corneal reflex brisk. Incision into trachea. Breathing ceased. Artificial respiration with lowered head and traction of tongue. Pulse feeble. Tracheotomy tube inserted. Pulse now imperceptible. A few breaths, one very deep, through the tube. Injections of strychnine. Artificial respiration kept up, but heart never recovered.

" *Post Mortem.*—Large swelling below jaw on right side, consisting of cellular tissue and glands. Epiglottis, larynx, and upper part of trachea in state of acute œdema. Lungs very congested. Heart enlarged, weighing 21 ounces ; much fat ; muscle soft. Death due to ' syncope from myocarditis accelerated by anæsthetic.' "

This case illustrates the fact that the danger of these acute inflammatory conditions of the neck is not merely due to the

obstructed breathing caused by the accompanying œdema of the glottis. This is relieved by opening the trachea. The toxic condition of the patient generally, and of the heart muscle in particular, however, may render recovery impossible during anæsthesia, even after the breathing is relieved.

Another case, the details of which were supplied to me by the administrator, illustrates well the danger of prolonged cyanosis when the patient has a heart which, though giving no murmur, is of impaired muscularity.

"A countryman of fifty, of medium height and build, but sallow complexion, had good health till pain in the rectum with a bloody discharge occasioned his admission into hospital. He was examined under an anæsthetic, a growth felt, and a laparotomy for its removal, if possible, decided on. Two days later he was given morphia and atropine. He was edentulous. Anæsthesia was induced quietly with C.E. mixture: there was difficulty in securing a free air-way owing to his edentulous condition. When fully under he was put in the Trendelenburg position. The colour of his face was blue. The cyanosis did not disappear when a free air-way was obtained. The abdomen was opened. The cyanosis was now so marked that oxygen was introduced and open ether substituted for C.E. mixture. The contents of the abdomen were manipulated and the growth in the colon pulled on. Cyanosis was extreme. Suddenly the breathing stopped. A few gasps were then drawn at long intervals. The heart was grasped by the surgeon, but no contraction could be felt even when the diaphragm was incised to allow of more effective massage of the organ.

"*Post mortem* the heart weighed 17 ounces and the muscle was soft; the lungs were œdematous. There was a fixed malignant mass in the sigmoid colon."

Inquiries into Deaths during Anæsthesia—Anæsthetists' Responsibility—Educational Questions

Germane to this part of our subject is the question of the *responsibility of the anæsthetist towards the patient.* Has he any direct legal responsibility, or are his services merged in those of the operator? Education of the student in anæsthetics and inquiries into deaths during anæsthesia are allied subjects that we may profitably examine here also. The *Lancet* [1] in a leading article not many years ago wrote: "The matter of the responsibility of operating surgeons and anæsthetists has been ventilated in connection with inquests held upon patients dying under anæsthetics, but it is not a little surprising that a subject so important to the profession and to the public at large should have received so little attention in works dealing with anæsthetics and published in the United Kingdom." When the public is mentioned we touch the crux of the whole question. While

[1] *Lancet*, Jan. 18, 1908.

public opinion is still widely ignorant of the important part which proper administration of anæsthetics plays in the safe conduct of operations, so long will the responsibility of the anæsthetist be ill defined and his true value underrated. At the present time we are in a transition stage. We are between the old days when the surgeon alone could be held responsible for the operation and all concerned in it, including the anæsthetic, and that future day when the clear individual responsibility of the anæsthetist will be recognized and justly assessed. As the *Law Journal*[1] states, "the apportionment of the responsibility for the anæsthetic between the operator and the anæsthetist is not clearly settled." Legally the matter has not been put to the test so far as inquiry enables us to discover. Actually in practice the modern surgeon has no doubt in his own mind. He assumes no responsibility at all for the anæsthetic under ordinary circumstances. His responsibility begins and ends with selecting a competent anæsthetist or consenting to operate when the anæsthetic is administered by some one chosen by the patient or by the practitioner. The exigencies of good surgery render it impossible for one man to operate and at the same time to watch the administration or effects of the anæsthetic. The surgeon to-day rightly insists that his hand and his brain should be entirely freed from all responsibility except that, heavy enough, which depends on the proper performance of his own task. The responsibility of the anæsthetic he leaves entirely to the anæsthetist. "If he selects or permits the selection of a person of small experience to administer the anæsthetic in a grave case, he assumes a serious responsibility."[2] This responsibility is often put upon him by the uninstructed indifference of the general public or by the circumstances of work in hospitals and similar institutions. Here and in practice in remote districts many operations have to be performed under circumstances which render the presence of a skilled anæsthetist impossible. To put it plainly, there are not enough experts to go round. Nevertheless, skilled or unskilled, the administrator is responsible for the effects of his anæsthetic. In hospitals and similar institutions the responsibility of the administrator is the same as that of the outside practitioner who administers an anæsthetic. The authorities of the institution are responsible only to the extent of showing due care in the selection of those who are allowed to give anæsthetics to the patients within its walls. Those who give the anæsthetics are responsible for their own actions. Consequently it would be perfectly reasonable for any junior officer, confronted with a case which he regarded as particularly risky, to refuse to

[1] December 14, 1907.
[2] *Lancet*, March 21, 1908, p. 851.

give the anæsthetic and to ask for the services of one of the specialists attached to the hospital. Such circumstances do, in fact, not infrequently arise. The same thing occurs in private practice. In emergency cases, however, both in and out of hospital, practitioners often have no option but to take the risk. Nor in the event of a fatality under such circumstances can they be justly blamed. They have done the best possible for their patients. When in hospital a student is giving an anæsthetic under the supervision of a qualified senior the latter must be held responsible. The student's acts are not his own, being directed and controlled by his instructor. Under exceptional circumstances it happens that a medical man has both to give the anæsthetic and perform the operation. In order to justify this he must be able to prove conclusively, in the case of a fatality, that it was the patient's best chance for the practitioner to take on the double duty instead of spending time in getting a second medical man. Deaths during dental operations at which the operator has also been the anæsthetist have happened on several occasions. The practice has been condemned by coroners' juries, but no legal action has hitherto arisen from it in this country, so far as the present writer is aware. Under ideal conditions every anæsthetic should be given by or under the supervision of an expert. The nearest approach we can make to this is to ensure by our training of medical students that no man obtains qualification without having good instruction and fair experience in the administration of anæsthetics. This first step has been taken, though not in full. Some, but by no means all, of the examining bodies in Great Britain require of candidates evidence that they have received instruction in anæsthetics.

So far as **legal restraint** is concerned there is nothing to prevent any person whatsoever from administering any kind of anæsthetic for any operation. Nor does it seem likely that the law will move, for as long ago as 1910 a Departmental Committee of the Home Office reported upon deaths resulting from the administration of anæsthetics and formulated certain recommendations. These recommendations were similar to those arrived at by the General Medical Council. No step at all has been taken. The recommendations of this Home Office Report are worthy of reproduction. They are :—

(1) Every death under an anæsthetic should be reported to the coroner, who, after inquiry, should determine whether it is desirable to hold an inquest or not.

(2) In the case of every death under an anæsthetic the medical certificate of death should specify the fact, whether the anæsthetic was the actual cause of death or not.

(3) No general respirable anæsthetic should be administered by any person who is not a registered medical or dental practitioner.

(4) Registered dentists should be confined to the use of nitrous oxide gas for dental operations, and should not employ the general respirable anæsthetics of longer duration.

(5) Intra-spinal anæsthesia should be practised only by registered medical practitioners.

(6) Practical and theoretical instruction in the administration of anæsthetics should be an essential part in the medical curriculum.

(7) Such instruction in the administration of nitrous oxide gas should be an essential part of the dental curriculum.

(8) In the case of any death under an anæsthetic in a hospital or other similar public institution there should be a scientific investigation into the actual cause of death conducted by the authorities of the institution.

(9) A small Standing Committee on Anæsthetics should be instituted under the authority of the Home Office.

The object of these reforms is the increase of public safety where anæsthetics are concerned. Every year there are a considerable number of fatalities during anæsthesia. We have seen good reason to believe that a certain proportion, probably a large proportion, of these are preventable. Their prevention depends upon raising the general standard of skill in administration of anæsthetics. This can only be brought about by improving the education of medical men in this matter, and this in turn depends on improving the status of the expert at the educational centres and requiring of him a professional degree and standing as high as that of the physician or surgeon. The anæsthetist's responsibility is in some respects as great as that of his colleagues. His position and rewards should not be greatly inferior to theirs. When the position of the teachers of anæsthetics is thus raised their influence on pupils will increase in proportion, the number of practitioners really competent in anæsthetics will consequently rise, and the desired reduction in avoidable fatalities will follow. Some improvement in the teaching of anæsthetics and the position of the teacher has come during recent years. That there is still room for progress, however, is obvious if we examine the arrangements of anæsthetics at various hospitals. These vary even among the London teaching schools. At one we find the anæsthetists placed on a level with the other honorary officers of the hospital. They manage their own department and are not subject to annual re-election. At another the position is very different. The anæsthetists have a place on the staff of the

medical school, but none on that of the hospital. They are subject to annual re-election and are paid officers of the hospital. At none, I believe, is there any stipulation as to the quality of degree which a candidate for the post of anæsthetist must hold. The more attractive the post of anæsthetist at a hospital can be made to the best type of student the better, of course, will be the men who hold these posts. And it is on the ability and enthusiasm of the holders of these posts that progress in anæsthesia, the training of students, and consequently the public safety ultimately depend. In some countries encouragement is given to nurses and other unqualified persons to give anæsthetics. That this practice, if widely prevalent, must lead to deterioration in the art and must stop all progress in anæsthesia is obvious. The anæsthetist under such an arrangement becomes a rule of thumb mechanic. He or she has neither the knowledge, the incentive, nor the opportunity for progress. He is not in a position to find out new things for himself or to impart them to others. An individual surgeon may find his work convenienced by having all his anæsthetics given by a subordinate trained exactly in limited duties and devoid of responsibility. To inculcate such a practice broadcast is to ensure the cessation of progress in the science and art of anæsthetics. In England the view taken by the General Medical Council with respect to "covering" makes it probable that a medical man who allows an unqualified person—and nurses are unqualified people—to give an anæsthetic for him renders himself liable to penalties. The opposite but similar condition, in which a medical man gave anæsthetics for the operations of an unqualified bone-setter, was held to justify the striking of the medical man's name off the Medical Register.

The *investigation of deaths under anæsthetics*, which might be an important road to knowledge, is at present largely wasted so far as concerns any attempt at scientific progress. Regarding coroners' inquests with the most lenient eye, no one could maintain that the coroner and his jury are fitted by training or experience to elucidate the truth where death during anæsthesia is concerned. It is true that some coroners insist on the *post-mortem* examination being made by a skilled pathologist. This is all to the good, but unfortunately the knowledge thus brought to light and recorded is often divorced from the clinical history of the case, and consequently both are wasted as regards advancing knowledge. If a death during anæsthesia takes place in a hospital, for instance, and the coroner, being duly informed, holds an inquest, the *post-mortem* examination is often made, not at the hospital, where are kept the records of the case, but at the mortuary attached to the coroner's court. The *post-mortem* records do not reach the

hospital. They can be got at only with difficulty and by the courtesy of the coroner. The very holding or not of inquests on anæsthetic deaths is anomalous. To begin with, medical men are not compelled by any statutory obligation to report cases of death during anæsthesia to the coroner. F. J. Waldo writes : " It is open to question whether he (the medical man) is not bound in common law to report such a death along with all others of a violent or unnatural kind." The medical man may well argue against this that the death during anæsthesia is no more of a violent or unnatural nature than other deaths which it is not customary to report to the coroner and on which no inquest is usually held. This leads us to the second striking anomaly which has been emphatically exposed by Mr. Justice Walton.[1] If a death under an anæsthetic is to be classed—as most coroners class it—under the heading of unnatural deaths, it surely follows, the judge points out, " that if the man died from an operation that plainly would be an unnatural death, and there would be an inquest in every case in which a man died from an operation." " The science of surgery would soon relapse into a retrograde condition if surgeons were called upon to justify in public every detail of their operations ; but it would appear that at present coroners think it their duty to put upon the rack of publicity only the unhappy anæsthetist." [2] It appears to be the only just and logical measure to treat deaths associated with anæsthetics in exactly the same way as those are treated that are associated with surgical operations. Can there be any justification for holding an inquest if a man dies from treatment on one day rather than on another ? Yet that is what holds at present. If as a result of operation and anæsthetic the patient dies on the operating table, an inquest is held. If he leaves the table and dies in bed twenty-four hours later equally as the result of operation and anæsthetic, no inquest is held. One unfair consequence of this procedure is that the public inevitably attribute the death on which an inquest is held to the anæsthetic. Yet we have seen how complex may be the origination of death during anæsthesia and how often the anæsthetic may not be the chief causative agent. An inquiry may, it is true, be justified on the grounds that, all the circumstances of the case being fully exposed, the relatives and friends of the deceased are able to be assured that the death was in no way attributable to neglect or lack of skill. Such assurance can equally be given by an inquiry that is not public. The publicity benefits no one, but it may seriously harm the medical men concerned. These inquiries

[1] *Trans. Med. Leg. Soc.*, Vol. 5, p. 76.
[2] Hewitt, *loc. cit.*, p. 649.

appear to us illogical in conception, useless in execution from a scientific point of view, and unfairly injurious in fact. Were they conducted in private and before a coroner assisted by experts something could be urged in their defence. In Scotland, as is well known, coroners' inquests are not held on these deaths. The Procurator-Fiscal is informed, makes his own inquiries, and generally orders a *post-mortem* examination by an expert. We cannot better end this part of our subject than by quoting Hewitt's words [1]: "The result is that the cause of death is determined without the public being alarmed by newspaper paragraphs, without the feelings of relatives being further wounded by a public inquiry, and without the anæsthetist—a man deserving rather of sympathy than censure—being called upon in public to submit to what often amounts to a severe cross-examination"

[1] "Anæsthetics," p. 651.

AUTHORS' NAMES

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